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Study of Earth Observation Business Models by Means of the Business Model Canvas Methodology

Master's Thesis – Report

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1. Previous Considerations

This chapter aims to frame the present study by communicating the ideas, observations and learning process that lead me to it.

This master's thesis is developed within the framework of the European Commission's DISCOVERER project (DISruptive teChnOlogies for VERy low Earth oRbit platforms), which is aimed at studying the possibilities of the so-called very low Earth orbits (VLEO[1]). More precisely, this project's work package devoted to studying business models for Earth Observation (EO) is developed at Universitat Politècnica de Catalunya (UPC), where I study.

While researching the VLEO topic during the initial phase of the project I found out that professionals with experience in this field highlighted [1] that it would be of great interest to improve our understanding of the implications of a fractionated space mission architecture (spreading the payload among a number of smaller satellites, each carrying one only sensor) versus a more traditional monolithic architecture (putting all the required sensors on a bigger satellite). Taking that into account, I decided to work on the following: choose an interesting application for EO and develop two versions of the mission analysis and design -based on a monolithic and a fractionated architecture- to later study and compare the viability in terms of schedule, performance and cost of the two options. The DISCOVERER project had chosen Planet Labs' 3-U nanosatellites constellation as a common reference, so the fractionated mission in my study would use that form factor too.

I found that project immensely interesting, albeit quite adventurous. I chose to develop a mission that would collect EO data to be used to develop a jellyfish forecasting application; this would have a direct impact not only on European SMEs (Small and Medium Enterprises) but also on European people and marine resources. It was not until

[1] Earth orbits with altitudes between 160 km and 450 km.

I learnt which parameters can be used to create a neural network to forecast jellyfish (namely surface temperature, salinity, chlorophyll content, sea-surface height and currents) that I was able to find out which satellite sensors would be required. Knowing that the payload constitutes 15-50% [2] of a satellite -around 0.75-2.5 kg in a 3U CubeSat- I discovered that the sensors required were two orders of magnitude too heavy. This means that this project did not pass its feasibility study: it was not possible to develop it within the time, economic and resources constraints.

To see the work developed to get here, refer to the Annex.

However, this experience turned out profitable because it gave me valuable insights. I believe the main mistake I made when I considered that approach was that I hugely underestimated the merit of Planet Labs' achievement of fitting a fully capable system into a satellite about the size of a loaf of bread. That made me reflect on how this startup, which amazed us all launching 88 satellites at once in a record-breaking launch just the day prior to DISCOVERER's group kick-off meeting, might indeed be shifting the space paradigm.

It seemed essential to me not to simply reproduce Planet Labs' marketing and report its achievements, but rather get a real vision of the situation. For a more comprehensive approach and properly judging the facts, I found it meaningful to compare the disruptive Silicon Valley startup with a consolidated top EO company with a more traditional approach: DigitalGlobe.

This study tries to answer questions like: who is Planet Labs and what is its mission? Who is DigitalGlobe and how did it become a leader in the space industry? Is Planet Labs really making a difference? How do Planet Labs and DigitalGlobe compare to each other? And finally: what are the key factors that make them succeed in the EO market?

2. Introduction

This chapter includes the aim, scope, requirements and justification of this study.

2.1 Aim

The aim of this project is to study and compare two big players in the Earth observation market to identify the key success factors of their business models.

2.2 Scope

This study will:

- Develop a descriptive case study for each company
- Draw the Business Model Canvas for each company
- Describe the two business models
- Compare the two business models with each other
- Analyse the business models
- Identify the key success factors of the two companies

This is a qualitative study, therefore it will not:

- Develop quantitative analysis

2.3 Requirements

- The two companies must have relevant positions in the Earth observation market.
- Each case study must be designed with a comprehensive list of sections covering all key topics to guarantee a complete and unbiased description.
- The case studies of the two companies must include the same contents to guarantee neutrality.

2.4 Justification

The space industry has experienced a revolution in the last years, with space entrepreneurs receiving unprecedented amount of venture capital (VC) funds to develop business plans centred in small satellites [3]. Technology miniaturisation, standardisation and reduced costs are favouring a massive use of these type of satellites by corporations that are increasingly adopting constellation-based mission designs. As Figure 1 shows, SpaceWorks foresees this will lead to an exponential growth that will result in between 2,000 and 2,750 nano- and microsatellites to be launched during 2014–2020, more than four times the amount in 2000–2012.

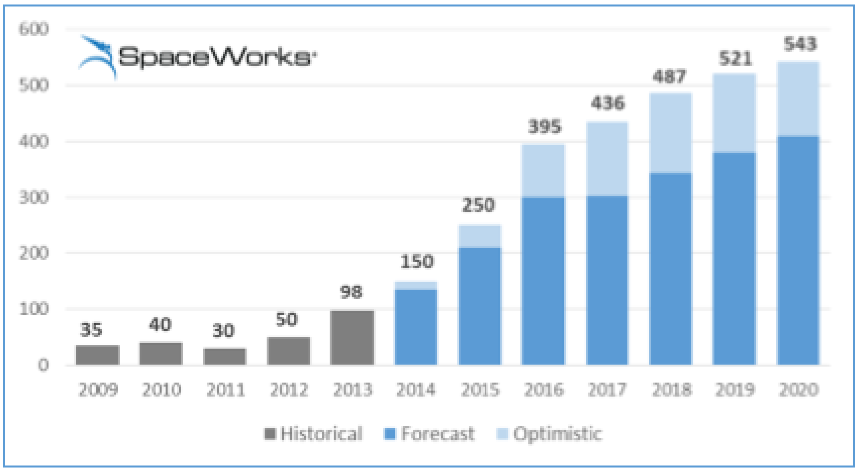

Figure 1 SpaceWorks' Nano- and microsatellite launch history and projection. Source: [4]

Nano- (1–10 kg) and microsatellites (10–100 kg), accessible platforms originally used for university projects or technology demonstration missions, have become popular in the business community, that is supporting space startups with new business models entering this previously slow-moving industry. This opens the door for new markets based on downstream applications, namely image analytics, asset tracking and high-speed data connectivity [3].

While small satellites have many potential applications, NSR (Northern Sky Research) found [3] that Earth observation has emerged as key driver for the growth of the industry, presumably due to a lack of available data for verticals like agriculture, forestry and wildlife, disaster management and financial services [3]. In its assessment on nano- and microsatellite markets, the consulting firm specialised in satellite and space market found that 40% of the nano- and microsatellites planned to be launched by the end of year 2024 will be for EO applications (see Figure 2), contributing a 58% of the total manufacturing market (around $400) [3].

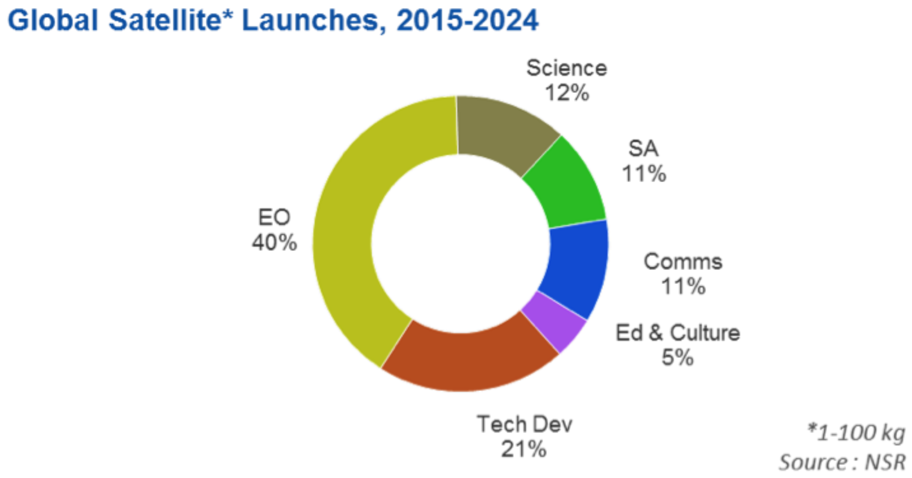

Figure 2. Forecast of nano- and microsatellites applications for 2015–2024. Source: NSR [3]

According to NSR [3], this demand for EO services using small satellites is mainly being driven by data-driven and consumer-oriented applications that may hold promise of unlocking previously unexploited markets. Figure 3, showing the 2020-projection for sales volume of EO products and services in the European market, illustrates how this market is expected to keep growing.

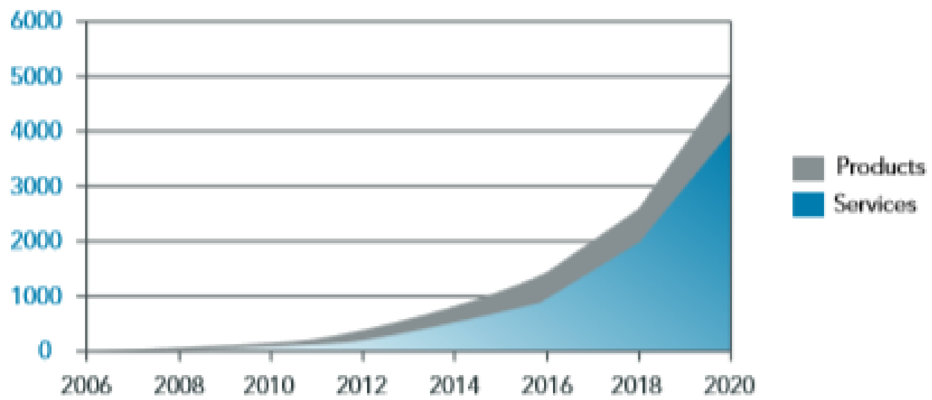

Figure 3 Projection for global European annual satellite EO products and services turnover, in millions of euros. Source: mission study –ISU-MSS. Extracted from[5]

Since the new space companies entering the EO market are using a different satellite size class, they are also changing the performances of the available EO data. The following figure illustrates this; Figure 4 suggests that the application market demand, in the top right blue part of the diagram, could either be met by a big satellite with very-high spatial resolution and medium temporal resolution or by a small satellite with very-high temporal resolution and medium spatial resolution.

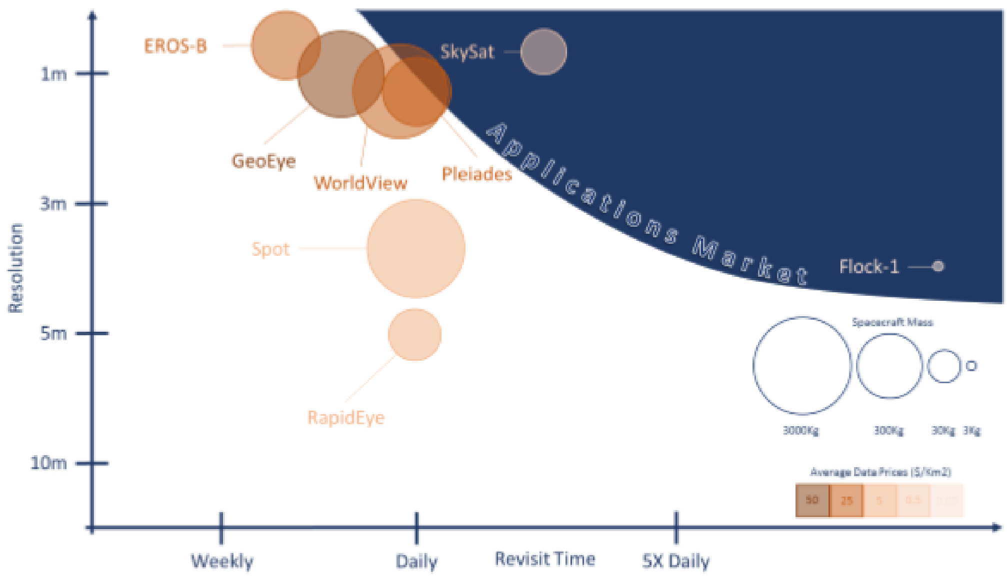

Figure 4 Spatial and temporal resolutions of satellite constellations according to the satellite size class. [4]

Historically, governments (in particular intelligence agencies and the military) have been the biggest customers of commercial EO data due to the high cost of those high-performance products. Now, the aforementioned diversification of the technical specifications of EO products allows to widen the target market and creates a paradigm shift not only in terms of technology but also in terms of business.

Interestingly enough, the expectations aroused by new space startups have generated mixed opinions regarding the sustainability of their business models and their likelihood of succeeding. In this context, the present study aims at shedding light on this matter.

3. State of the Art of EO

This section includes a catalogue of the most relevant EO missions by the European Space Agency (ESA), which are accepted as representative of the space missions targeting the benefit of the European population.

In the absence of an only source cataloguing all these missions and including all of the detailed information required here, I proceed to collect all the information I consider relevant from numerous sources. Finally, this information coming from around thirty different sources is gathered together in the following tables.

Legend:

- Blue: ocean- and sea-related mission objectives (4 missions out of 15)
- Turquoise: multiple applications (4)
- Green: vegetation-related mission objectives (1)
- Red: meteorology-related mission objectives (3)
- Orange: atmosphere studies (3)

If we patiently take a look through this large amount of information we can find tendencies that can teach us something, which is exactly what all the work behind this was aiming to. There are some relevant hints standing out from the big picture:

1. As the previous numbers in brackets show, the applications of the missions are quite evenly distributed.
2. The vast majority of missions use a Sun-synchronous orbit (SSO).
3. Before Envisat, all missions listed worked with one single satellite. Envisat, while being designed as a one-satellite mission as well, started working in tandem campaigns with ERS-2. And after that, all missions studied are designed with more than one satellite, always using 2 simultaneously (except for MetOp which uses 3).

Table 1 ERS (European Remote Sensing). Sources: [6]–[9]

Mission	Op. life	Launcher	Sats.	Sats. mass (kg)	Instr. /sat.	Instruments	Altitude (km)	Orbit	Objective
ERS-1	1991–2000	Ariane 4	1 (worked as the first tandem mission for nine months with ERS-2)	2384	6	RA (Radar Altimeter) MWR (Microwave Radiometer), to measure atmospheric liquid water content, as correction terms for the radar altimeter signal ATSR (Along Track Scanning Radiometer), consisting of an Infra-Red Radiometer (IRR) and a Microwave Sounder (MWS) SAR (Synthetic Aperture Radar) with image and wave modes WS (Wind Scatterometer) PRARE (Precise Range And Range-Rate Equipment), a compact microwave satellite tracking system	785	SSO	Study the ocean surface temperature and winds at sea
ERS-2	1995–2011	Ariane 5	1 (worked in tandem campaigns with ERS-1 and Envisat)	2516	7	RA (Radar Altimeter) MWR (Microwave Radiometer), to measure atmospheric liquid water content, as correction terms for the radar altimeter signal ATSR (Along Track Scanning Radiometer), consisting of an Infra-Red Radiometer (IRR) and a Microwave Sounder (MWS) SAR (Synthetic Aperture Radar) with image and wave modes WS (Wind Scatterometer) PRARE (Precise Range And Range-Rate Equipment), a compact microwave satellite tracking system GOME (Global Ozone Monitoring Experiment), ultraviolet and visible spectrometer for global monitoring of atmospheric Ozone	785	SSO	Study the ocean surface temperature and winds at sea plus the ozone levels in the atmosphere

Table 2 Proba (PRoject for OnBoard Autonomy). Sources:[10]–[13].

Mission	Launch	Launcher	Sats.	Sats. mass (kg)	Instr. /sat.	Instruments	Altitude (km)	Orbit	Objective
Proba-1	2001	Antrix /ISRO PSLV-C3	1	94	8	CHRIS (Compact High Resolution Imaging Spectrometer), for the collection of BRDF (Bidirectional Reflectance Distribution Function) data for a better understanding of spectral reflectances HRC, a black-and-white camera with a miniaturised telescope	615	SSO	Use and demonstrate automatic functions, both onboard and in the mission ground segment (technology demonstration mission). Can be used for environmental monitoring, crop forecasting, forest cataloguing and marine science. The technology objective is to explore the capabilities of imaging spectrometers on agile small satellite platforms.
Proba-V (Vege-tation)	2013	Vega	1	140	1	One single operational payload: Vegetation instrument: high-resolution imaging spectrometer 5 technological payloads in the frame of the In Orbit Demonstration: X-Band transmitter based on the new GaN RF amplifier EPT (Energetic Particle Telescope), demonstrating a new type of radiation monitoring sensors and acquisition system SATRAM radiation monitoring system, complementing EPT ADS-B (Automatic Dependent Surveillance Broadcast) receiver, demonstrating potential air traffic surveillance from LEO satellites HERMOD (fibre optic connectivity in-situ testing)	820	SSO	Map land cover and vegetation growth across the entire globe

Table 3 Envisat, Meteosat and MetOp. Sources: [14]–[24].

Mission	Launch	Launcher	Sats.	Sats. mass (kg)	Instr. /sat.	Instruments	Altitude (km)	Orbit	Objective
Envisat	2002–2012	Ariane 5	1 (worked in tandem campaigns with ERS-2)	8,000	10	ASAR (Advanced Synthetic Aperture Radar) MERIS (Medium Resolution Imaging Spectrometer) AATSR (Advanced Along Track Scanning Radiometer) MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) GOMOS (Global Ozone Monitoring by Occultation of Stars) DORIS (Doppler Orbitography and Radio-positioning Integrated by Satellite) RA-2 (Radar Altimeter) MWR (Microwave Radiometer) LRR (Laser Retro Reflector)	772	SSO	Study the Earth's land, atmosphere, oceans and ice caps
MSG (Meteosat Second Generation)	2002 (MSG-1) 2005 (MSG-2) 2012 (MSG-3) 2015 (MSG-4)	Ariane 5	4 in total. Only 2 simultaneous	2,000	3	SEVIRI GERB (Geostationary Earth Radiation Budget) Search & Rescue : 406 MHz transponder	3,5786	GEO	Obtain data and images for operational use by meteorologists

MetOp (Meteorological Operational)	2006 (A), 2012 (B) & 2018 (C)	Soyuz /ST Fregat	3 identical	4,085	11	European: IASI (Infrared Atmospheric Sounding Interferometer) MHS (Microwave Humidity Sounder) GRAS (GNSS Receiver for Atmospheric Sounding) ASCAT (Advanced SCATterometer) GOME-2 (Global Ozone Monitoring Experiment–2) optical spectrometer Heritage instruments provided by NOAA and CNES: AMSU-A (Advanced Microwave Sounding Unit-A) AVHRR (Advanced Very High Resolution Radiometer) HIRS (High-resolution Infrared Radiation Sounder) A-DCS (Argos Advanced Data Collection System) SARSAT (Search & Rescue) SEM-2 (Space Environmental Monitor)	817	SSO	Europe's first polar-orbiting mission dedicated to operational meteorology
MetOp-SG (Meteorological Operational Second Generation)	2021 (A), 2022 (B), - -	Soyuz-class. Also compatible with Ariane and Falcon 9	6 in total. Only 2 different simultaneous	MetOp-SG-A: 3,000–4,000	8	METimage (Visible Infrared Imager - DLR) MWS (Microwave Sounder - ESA) IASI-NG (Infrared Atmospheric Sounder Interferometer-Next Generation - CNES) RO (Radio Occultation - ESA) 3MI (Multi-view Multi-channel Multi-polarization Imager - ESA) Radiation Energy Radiometer (NOAA) Low Light Imager (NOAA) UVNS/Sentinel-5 (ESA/Copernicus)	817	SSO	To provide operational observations and measurements from polar orbit for numerical weather prediction and climate monitoring in the 2020 to mid-2040's timeframe. In addition, to provide services to atmospheric chemistry, operational oceanography and hydrology. With respect to the first generation of MetOp satellites: to ensure continuity of essential operational meteorological observations from polar orbit, without a gap; to improve the accuracy of the measurements; to add new measurements
				MetOp-SG-B: 2,400	7	MWI (Microwave Imaging Radiometer - ESA) ICI (Ice Cloud Imager - ESA) SCA (Scatterometer - ESA) RO (Radio Occultation - ESA) Argos-4 (Data Collection Service - NOAA/CNES) Search and Rescue (COSPAS-SARSAT) Space Environment Monitor (NOAA)			

Table 4 Sentinels family of two-satellite missions. Sources: [21]–[32].

Mission	Launch /service life	Launcher	Sats.	Sats. mass (kg)	Instr. /sat.	Instruments	Altitude (km)	Orbit	Objective
Sentinel-1	2014 (A) and 2016 (B)	Soyuz	2	2,300	1	C-SAR (C-band Synthetic Aperture Radar)	693	SSO	Land monitoring of forests, water, soil and agriculture Emergency mapping support in the event of natural disasters Marine monitoring of the maritime environment Sea ice observations and iceberg monitoring Production of high resolution ice charts Forecasting ice conditions at sea Mapping oil spills Sea vessel detection Climate change monitoring
Sentinel-2	2015 (A) and 2017 (B)	Vega	2	1,140	1	MSI (Multispectral imager)	786	SSO	Monitoring agriculture, forests, land-use change, land-cover change; mapping biophysical variables such as leaf chlorophyll content, leaf water content, leaf area index; monitoring coastal and inland waters; risk mapping and disaster mapping
Sentinel-3	2016 (A) and 2017 (B)	Rockot	2	1,150	4	OLCI (Ocean and Land Colour Instrument) SLSTR (Sea and Land Surface Temperature Radiometer) SRAL (Synthetic Aperture Radar Altimeter) MWR (Microwave Radiometer)	815	SSO	Measure sea-surface topography, sea- and land-surface temperature, ocean colour and land colour with high accuracy and reliability. Support ocean forecasting systems, as well as environmental and climate monitoring.

Sentinel-4	≥2022 to ≥2037	To be carried on MTG-S1 & MTG-S2	2	allocated mass 200 kg	1	UVN (Ultraviolet Visible Near-infrared) high-resolution spectrometer The Sentinel-4 mission also comprises data from Eumetsat's thermal InfraRed Sounder (IRS), embarked on the MTG-Sounder (MTG-S) satellite too, and data from Eumetsat's Flexible Combined Imager (FCI) embarked on the MTG-Imager (MTG-I) satellite.	3,5786	GEO	Monitoring the composition of the atmosphere. Services will include the monitoring of air quality, stratospheric ozone and solar radiation, and climate monitoring.
Sentinel-5	3 models, launched at 7-year interval	(see)[2]	2	allocated mass 270 kg	1	UVNS (Ultra-violet, Visible and Near-infrared Sounder) high-resolution spectrometer The Sentinel-5 mission also comprises data from Eumetsat's IRS, the Visible Infrared Imager (VII) and the Multi-viewing Multi-channel Multi-polarization Imager (3MI).	830	SSO	Monitoring the composition of the atmosphere. Services will include the monitoring of air quality, stratospheric ozone and solar radiation, and climate monitoring.

[2] The Sentinel-5 mission is a payload, consisting of a single instrument named UVNS. It will be hosted as a CFI (Customer Furnished Item) on a polar-orbiting MetOp SG spacecraft.

Sentinel-6	≥2020 to ≥2026	Falcon 9, Atlas 5 or Antares	2	1,440	6	Poseidon-4 (SAR Radar Altimeter) AMR-C (Climate-quality microwave radiometer – NOAA/JPL contribution) GNSS–POD: receiver provides GNSS measurements for Precise Orbit Determination using GPS and Galileo signals DORIS: enables precise orbit determination, as well as providing on-orbit position to the altimeter for use with its built-in DEM Laser Retroreflector Array (NOAA/JPL contribution): enables tracking by ground-based lasers GNSS-RO (NOAA/JPL contribution): uses GNSS measure- ments for RO	1,336	non-SSO, 66º	Measure global sea-surface height, primarily for operational oceanography and for climate studies. Designed to complement ocean information from Sentinel-3.

4. Case Study: Planet Labs

This chapter is the case study about the Silicon Valley –based startup Planet Labs, also known as simply Planet.

Both this and the case study about DigitalGlobe (in the following chapter) belong to the category called descriptive case studies and aim to offer a complete description of each company. It has not been possible to directly interview the firms; therefore the information has been gathered mostly from their corporative websites; published interviews; conference proceedings, slides and videos; technical reports and magazine articles.

4.1 History and Company Overview

Planet Labs was officially founded in December 2010 under the name of Cosmogia Inc. [38]. But its history begins some years before when the founders, three young NASA scientists, met at the United Nations trying to find a way to use space to help people around the planet, protect biospheres and stop deforestation [39].

They were Robbie Schingler (MBA from Georgetown University, Master of Space Studies from the International Space University and BSC in Engineering Physics from Santa Clara University), Will Marshall (PhD in Physics from the University of Oxford, MSc in Physics with Space Science and Technology from the University of Leicester) and Chris Boshuizen (PhD in Physics from the University of Sydney). They came from three different continents, but they realised they shared a feeling of disillusionment with the established space industry. Specifically, with how it had become trapped in a tradition of requirements-driven approaches to design and testing, because that was leading to increasingly unaffordable spacecraft in terms of cost, mass and schedule [40].

Landsat 8[3], for instance, cost the US government about $850 million to build and launch, and five years of operations are estimated to raise the total to nearly $1 billion [41]. Landsat 8 was launched in 2013—years after the three scientists decided to leave NASA—illustrating how the old approach that had frustrated them was far from changing. That same year, in fact, the White House asked NASA to find how to drive down the collection cost of future Landsat data, directing the agency to design what they called a "sustainable and sustained" system of spacecraft [41]. Earth Science Division Director Michael Freilich argued they had thought of several "more or less viable architectures, but none of them is perfect" [41] and claimed that "the problem would be a whole lot easier if we had a lot more money" [41]. None of these make it look like the change was perceived as an urgent necessity by the space agency.

Marshall, Boshuizen and Schingler had long wanted to change the space industry [42]. They just had not found how to do it yet, and probably needed to find whom to do it with. It was the early 2000s when they met at an international conference held at the United Nations aimed at young professionals to make policy recommendations on how space could benefit humanity [43]. That event would bond them to a global community of scientists and led to a relationship of regular collaboration over the next decade. Together, they wrote a paper for the European Union about space policy. It was a statement that they decided to join efforts to put together a report at a conference where no one was willing to put individual merits aside in the interest of making a higher contribution. That collaboration across different time zones required many phone calls at inconvenient hours but gained them a valuable experience in making big, international projects happen [42]

Some time afterwards the three of them were working on small scientific satellites at NASA Ames Research Centre [43]. There, Engineering Director Pete Klupar would often hold his Blackberry in his hand and ask his staff why satellites were so expensive and carried outdated technology. "My smartphone is better than your spacecraft", he used to say [44]. After hearing this a few times, Chris Boshuizen and Will Marshall realised how smart that thought was.

[3] EO satellite built by the collaboration between NASA and the United States Geological Survey (USGS).

This was exactly the idea behind PhoneSat, a NASA project devised by Boshuizen and Marshall that put a mobile phone with extra batteries aboard three CubeSats to be launched in 2013. Again, by that time they two, together with Schingler, would have already left NASA to found their own startup [44].

In 2005 they started living in a house together and, in what today would be considered a typical Silicon-Valley style, turned their garage into a workshop where they spent the weekends playing with satellite technology (shown in Figure 5). When it got more serious, they started hiring friends. Eventually, they decided to leave the space agency. It was in that garage that they built their first satellite, called Dove. While it has become quite standard now for startups to start in a Silicon Valley garage, they proudly claim to be the first ones to literally build a satellite in such place [39].

Figure 5 Planet's founding team building satellites in a Cupertino garage in November 2011. Source: [45]

In February 2012 the startup moved into the SoMa coworking space in the trendy South of Market neighbourhood in San Francisco, where it remains today [42]. Other than its premises in the US (San Francisco and Mountain View in California, and Seattle in Washington), it has offices in Amsterdam and Berlin. From there, its imagery is delivered to an International network of customers and partners in over 100 countries [46]

Reinventing space business is not easy, but Planet Labs has been quite consistent in its announced launch program. It launched its first satellites in 2013 [47]. Two years later, in July 2015, the company announced its future acquisition of BlackBridge and its RapidEye 5-satellite constellation, together with an archive of 6 billion square kilometres of imagery captured over the previous years [48].

By the time that acquisition was complete in October 2015 [47]—five years after being founded—Planet Labs was already operating the largest constellation of Earth-imaging satellites ever. Only months after, the corporation signed an introductory contract with the NGA (National Geospatial-Intelligence Agency), the largest of geospatial customers [49].

The business has kept expanding at a fast pace since early 2017. After hitting the headlines with their record-breaking launch of 88 nanosatellites on February 15 and bringing the constellation of Doves to 144, on April 19 this year the company announced it had completed the acquisition of Terra Bella, a rival satellite imaging company. It also confirmed that, as part of the deal, Google was now a noteworthy shareholder in the firm. Google had previously purchased Terra Bella (then named Skybox Imaging) in 2014 for an estimated price of $500 million [50]. In 2017 both Planet and Google have declined to disclose any other details about the deal other than the fact that Google has now a deal for some years to buy imagery from Planet [51]. Though Planet acquired Terra Bella business and satellites, the search engine giant will keep on licensing the satellite imagery for its mapping products such as Google Maps, so it will still keep control over the satellite imaging company [50].

Next summer (2017) the 88 doves launched in February will have been allowed six months to settle into their prescribed orbit. At that point, Planet Labs expects to reach its primary goal: to be able to image every point on Earth’s landmass at least daily, at resolutions up to 3.7 m [47]. As the startup likes to say, good enough to count all the large trees on our planet. And of course, recount them every day to make sure they are still there.

4.2 Leadership and Employees

4.2.1 Leadership

Two of the three co-founders remain today in the company: Will Marshall and Robbie Schingler. Will Marshall is CEO (Chief Executive Officer), leading the overall company strategy and direction. Robbie Schingler, who spent 9 years at NASA, is now Planet's Chief Strategy Officer.

In November 2015 the third co-founder, Chris Boshuizen, who at that time was responsible for satellite production and the leadership of the engineering team as CTO (Chief Technology Officer), announced via Twitter he was leaving the company (Figure 6).

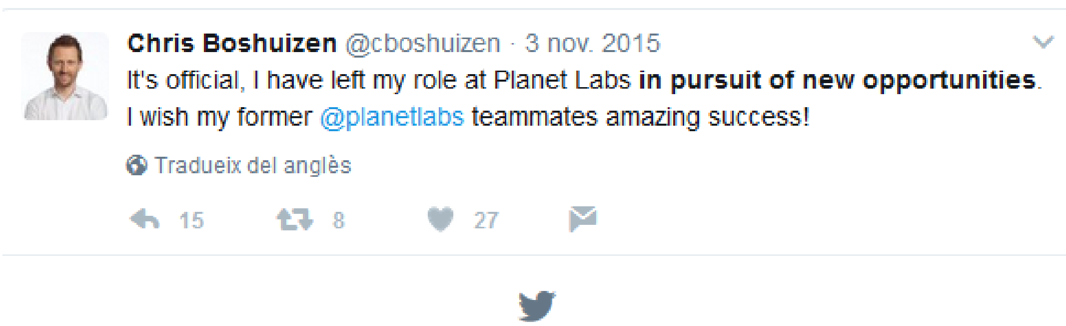

Figure 6 Boshuizen's twit. Source: Chris Boshuizen Twitter account.

Along with Schingler and Marshall, there are seven more people in management positions in Planet Labs these days providing their lengthy experiences. Among them, Tom Barton is responsible for the company's business operations and Ryan Johnson the President, whereas Karthik Govindhasamy leads the engineering section and David Oppenheimer is in charge of the financial aspects. Diagram in Figure 7 has been specially designed for this case to show all nine people leading the company.

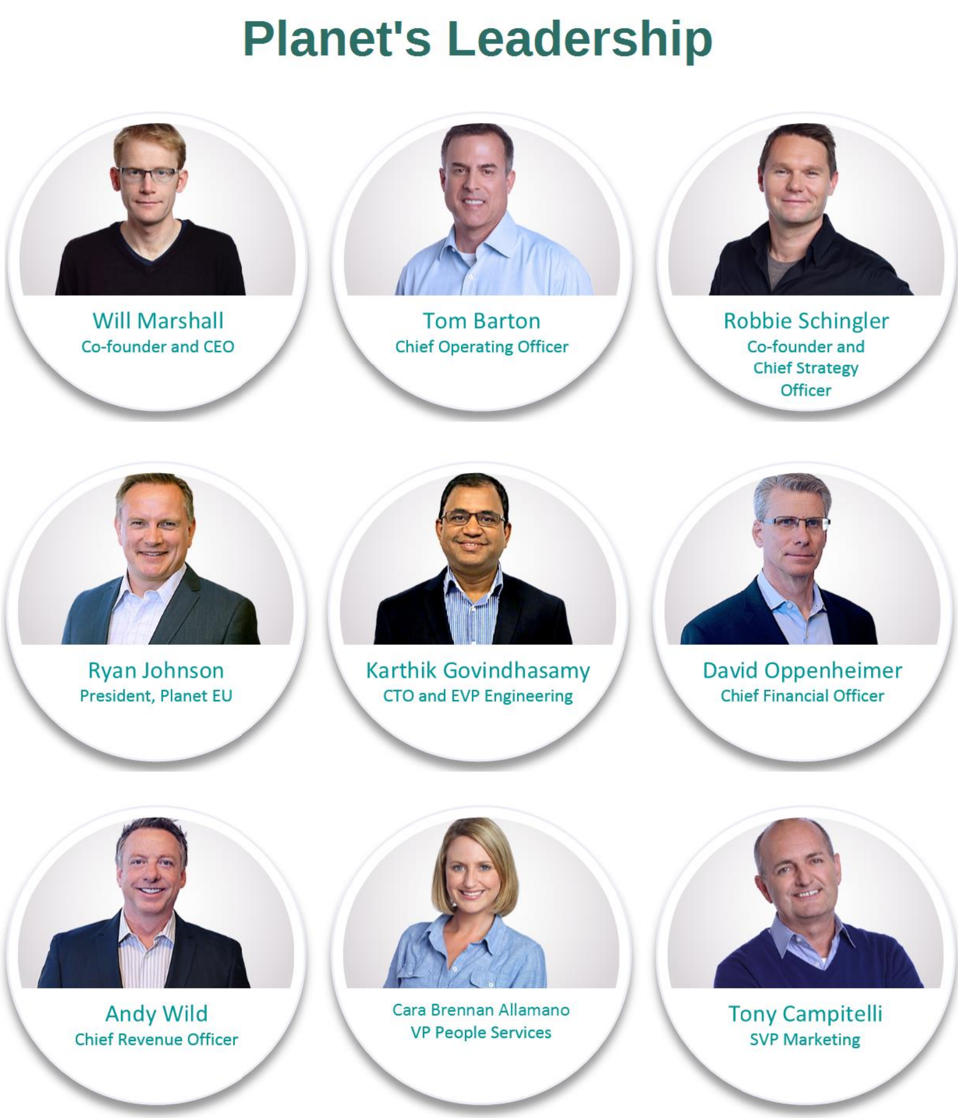

Figure 7 Planet's Leadership team. Author's composition using the information from [49].

4.2.2 What a Planeteer Looks Like

The number of employees at Planet has been experiencing exponential growth. The figure was reportedly 40 in January 2014 [44], rose to 100 in March 2015 [52] and reached over 300 in April 2016 [53].

While the organisation has not released any statistics about its employees' profile, anyone looking at Planet's images on the media will notice a predominance of young people. Whether it is a fact of literal young age or rather young spirit (Figure 8), the truth is all those images show a fresh, open and creative atmosphere—noticeably less formal than the average space enterprise, although somewhat typical of Silicon Valley.

Figure 8 Planet staff. Source: [54].

It is not just that Planet's leaders have created a non-standard working environment; it also feels like they are well aware of it—and proud. On the organisation's website there is a mini-series of videos called *Meet a Planeteer.* In each one, a *Planeteer* (this is how Planet employees call themselves) introduces her- or himself.

One of the videos features an onboard software engineer (one who happens to wear fluorescent green hair). He, a young open-source coding enthusiast, stresses how much he values that Planet strives for openness. He also explains how much fun he had in Christmas time when the company organised a gingerbread-spacecraft competition. “The gingerbread spacecraft even went through similar tests to the ones our real spacecraft get through”, he explains thrilled [55].

Another video stars Shireen, a Junior People Partner[4] holding an MSc in Psychology who previously worked in a jail and is now excited to work surrounded by space scientists [56]. A third video introduces a young Sales Manager called Giselle who especially appreciates the learning opportunities she has at the Planet and the mentoring she receives [57].

4.2.3 Work Climate at Planet

Some journalists who have visited Planet’s headquarters in San Francisco have reported its creative, non-conventional environment: a drum set tucked in a corner, coders sitting on yoga balls and even a nap room with Star Wars sheets on the beds [58]. But however fun it may look from the outside and probably is, space is a very competitive and technically demanding business field, and that surely is translated into the frantic rhythm of work at Planet.

In the employees’ reviews of the company [59], no one conceals the fact that it is indeed a challenging job with long work days and always plenty of things to be done. Such an innovative approach does not help keep priorities clear nor maintain plans; it requires extra flexibility from everyone. But disrupting the space industry sure is exciting and having a humanity-centred mission definitely is motivating.

[4] Planet Labs’ name, presumably for HR positions.

4.3 Products

Planet Labs focuses on the market segment of very-high temporal resolution (daily revisit time) with medium spatial resolution (3 to 5 m). Its primary product offering is Earth imagery and imagery-derived data products. The company states that the key differentiators of its dataset are: one, complete coverage of the entire Earth's land area at a resolution not currently available, and two, daily revisit of this sampled land area [40].

On its website's FAQ (Frequent Asked Questions) section [60], a simple yet complete answer to the not-so-easy question "*what are your products?" i*s given. Instead of attempting to rephrase an already concise explanation, I rather reproduce the original text here:

> *Planet Labs' core products come from high-resolution satellite images that are offered as individual Scenes or composited Mosaics.*
>
> *Scenes are images as they are captured from the satellite and are available in two different product formats: visual and analytic. Mosaics are single-layer composites of a large region that has been intelligently crafted from Scenes. (…)*

In my opinion, it is arguable if Planet's imagery is *high resolution*. One could argue that a resolution of 3-5 m falls under the category of medium resolution, maybe medium-to-high resolution. Some analysts [4] emphasise the relevance of a sub-meter resolution, which they call *economic scale* and is being delivered by other companies. At the 2016 International Astronautical Congress, Mr Schingler in fact sustained that Planet shall not pose any privacy concerns because their spatial resolution was not enough to make out individual people [61]. In short, for a fair overall market perspective, it is good to keep in mind that (although it might be qualified as *high*) Planet's imagery is not among the *highest* resolutions in the market—because there are *very-high* resolutions too.

Planet operates two Earth-imaging constellations: PlanetScope (PS) and RapidEye (RE). The PlanetScope satellite constellation consists of multiple launches of groups of individual satellites (or *Flocks* of *Doves,* as Planet calls them). This makes the on-orbit capacity improve constantly in capability and quantity and allows to deploy technology improvements at a fast pace. Its data come in multiple spectral bands (blue, green, red and NIR, Near-Infrared) with a pixel size of 3–3.125 m. The GSD (Ground Sampling Distance) is 3 m (International Space Station – ISS orbit) and 3.7 m (Sun Synchronous Orbit – SSO), and the Image Capture Capacity (ICC) is 150M km^2 a day [62].

The RapidEye constellation, on the other hand, is made up of the 5 RapidEye satellites Planet acquired from BlackBridge. Its data comes again in multiple spectral bands (blue, green, red, red edge, and NIR); the pixel size is 5 m. It has a GSD of 6.5 m and an ICC of more than 6M km^2 per day [62].

Both PlanetScope and RapidEye imagery products are available in different processing levels to be directly applicable to customer needs. This is what the company refers to when it mentions “individual Scenes” and “composed Mosaics”. Such Mosaics are actually called *Tiles* in the most recent release of Planet Imagery Product Specification report [62].

According to this document, the PlanetScope constellation (the most representative one of Planet’s business model) offers three product lines:

- **Basic Scene product:** only radiometric and sensor corrections applied to the data; product intended for users with advanced image processing and geometric correction capabilities only.
- **Ortho Scene product:** radiometric and sensor corrections plus orthorectified product; image product suitable for analytic and visual applications.
- **Ortho Tile product:** radiometrically, sensor and geometrically corrected and aligned to a cartographic map projection.

Ortho Tiles, which are the most processed product, are Planet’s core product lines [62]. They are created from multiple orthorectified scenes in a single strip that have been merged and later divided according to a defined grid. Figure 9 is an explanatory picture of this which helps get the idea. Each Ortho Tile represents a real surface 25 km by 25 km and is referenced to a fixed, standard image tile grid system. This is useful for many different applications requiring imagery with an accurate geolocation and cartographic projection [62].

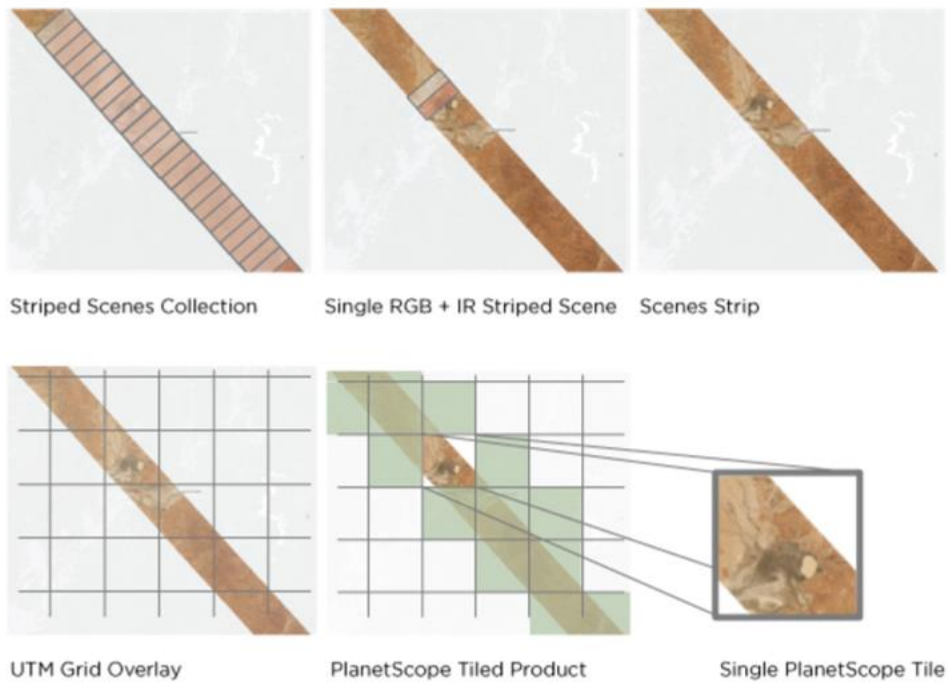

Figure 9 Conversion from Scene to Ortho Tile product. Source: [62]

In the previous definition of Planet's offerings, two product formats are mentioned: visual and analytic. Below are Planet's definitions for the two variants, including their intended used (extracted from [62]):

> *The Visual product is optimal for simple and direct use of the image. It is designed and made visually appealing for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection.*

On the contrary,

Analytic products are calibrated multispectral imagery products that have been processed to allow analysts to derive information products for data science and analytics. This product is designed for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. (..)
The orthorectified visual imagery is optimal for value-added image processing including vegetation indices, land cover classifications, etc.

This variety of products, with gradation of processing levels, is why Planet Labs usually claims to sell both raw images and value-added products. Finally, customers can access all Planet's imagery products through their API (Application Processing Interface) and GUI (Graphical User Interface) platforms.

The San Francisco–based startup's mission has always been not only to photograph the entire Earth every day but also to make these data accessible to everyone. In line with this, the company is reportedly [61] planning to make this imagery available to the public, using the offering model of free basic access on the one hand and premium accounts to more quantity and quality data on the other hand. For now, the firm has created an initiative called Open California through which it releases a portion of its California data archive to approved developers, image analysts and researchers. This is a limited release that will be evaluated annually [63].

4.4 Of Doves and Flocks

Satellites designed and built by Planet Labs are called *Doves*. Planet refers to a group of Doves deployed simultaneously into a single orbit as a *Flock*. A Dove is a standardised 3U CubeSat (10 cm by 10 cm by 30 cm) weighing 5 kg. Its payload is an optical system and camera: a Bayer Masked CCD camera with 90-mm aperture and RGB+NIR imaging with a resolution of 3–5 metres per pixel. [64]. Each of these shoebox-sized spacecraft is equipped with GPS (Global Positioning System) and a star camera that allow to position the image on Earth. The Dove's position is controlled through a combination of reaction wheels and magnetorquers, and it also includes radio antennas and fold-out solar arrays [65] that can be appreciated in Figure 10.

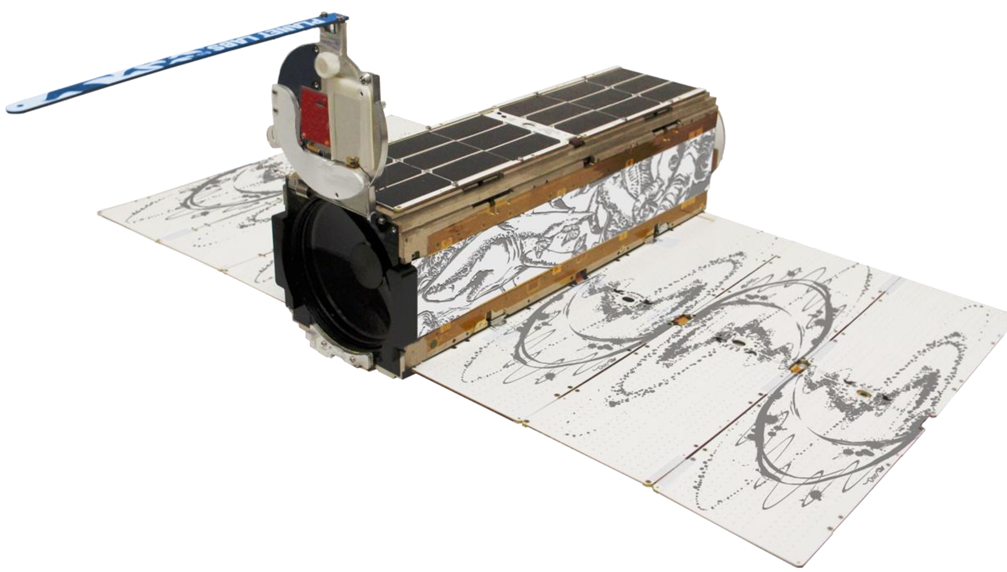

Figure 10 Dove. Source: [66]

Doves are designed to be frequently updated and replaced, having each an expected operational lifetime of 1 to 3 years, depending on the type of orbit. In order to keep this continuous cadence of launches, Planet uses an *agile aerospace* approach to technology development. This (explained in the following section) means it uses rapid iterative design and frequent testing in space, which results in continually deploying improved spacecraft and payloads.

The complete PlanetScope (Planet's constellation built up of Doves) is designed as a constellation of approximately 120 satellites to be able to image the whole land surface of the Earth every day (i.e. a daily collection capacity of 150 million km^2). This the updated constellation design reported in 2017 [62], whereas the original design included up to 150 spacecraft. It is my opinion that behind this readjustment there is probably an explanation similar to the story of Iridium—the constellation named after the chemical element with atomic number 77 which ended up reduced to 66 satellites. Of course, as the authors of reference book Space Mission Analysis and Design (commonly known as SMAD) remark [2], in comparison to *Iridium* the name *Dysprosium* (atomic number 66) is not as good.

Planet does not release great details about the constellation design. However, in my opinion these figures (previously 150, now 120 satellites) might indicate that the original design consisted of 5 orbital planes with 30 satellites each, whereas in the updated one the number of orbital planes would have been reduced to 4. Just like happened to Iridium, which had an initial design of 7 orbital planes with 11 satellites until the team of engineers realised one orbital plane could be cut down[5] if the constellation was redesigned. Iridium's story is a fact. The observation about PlanetScope is what I personally infer.

Planet's satellites are deployed into two types of orbits: International Space Station (ISS) orbits are at a 52-degree inclination at approximately 420 km altitude, and Sun Synchronous Orbits (SSO) are at 98 degrees inclination or higher at approximately 475 km altitude. Here too there has been a change in the company's plans. Whereas in 2015 Planet stated that "Large constellations of satellites will be operated in both orbit types" [67], the updated explanation on its website is the following [68]:

> *Our entire operational constellation will be in polar or sun-synchronous orbits. In addition, we use the same orbit as the International Space Station (ISS), at a 52-degree inclination, as a testing ground for our technology.*

In whatever orbit, Planet Labs' satellites operate in a constant monitoring mode. Doves are not tasked; instead, they continuously capture imagery of the sunlit portion of the earth's surface [67]. This characteristic of the mission operations is highly relevant to Planet's business model, as it is explained in the section below related to Planet's products applications (*Applications and Customers,* page 41).

[55] A smaller number of orbital planes has a number of advantages, namely: easier rephase of satellites within each plane, more frequent performance plateaus, more responsiveness to changing user needs, more graceful degradation and, more importantly, more responsiveness to political and performance demands [2].

Following this philosophy of reinventing the rules of the game, Planet is taking advantage of its numerous satellites produced to not just send technology alone to space but to also send art. The *Artist in Residence* program places artwork on the laser-etched side panels of each spacecraft (see Figure 10). “Planet has created the largest art show in Earth’s orbit”, the corporation claims [69]. An attention-getting and capitalised statement can be read on its website [69]:

WE HOLD A BEDROCK BELIEF IN THE POWER OF THE ARTS TO ENRICH, CHALLENGE AND EXPAND OUR UNDERSTANDING OF LIFE ON EARTH.

Despite how innovative Doves’ external appearance is, let us not be misled: the real breakthrough is what is on the inside. These spacecraft carry batteries normally found in a laptop and semiconductors similar to those in a smartphone. “Nothing here was prequalified to be in space”, Will Marshall said. “We bought most of our parts online” [70]. The following section (Production System) explains how this is achieved.

However, Planet’s most recent plans at the time of writing include broadening its fleet diversity. As previously noted, in February 2017 Planet Labs signed an agreement with Google, wherein Google would enter into a multi-year contract to buy Earth imagery from Planet while Planet would acquire the Terra Bella business and its SkySat constellation. That constellation comprises 7 high-resolution satellites, and Planet considers this a great opportunity to complement its existing more medium – resolution fleet. “The two systems under one roof will be truly unique and will enable valuable new capabilities”, Will Marshall wrote [71].

Although this agreement diversifies Planet’s fleet, it also combines two companies sharing a particular engineering philosophy. John Fenwick (Terra Bella co-founder) highlighted this fact [71]:

From the start, Planet and Terra Bella have shared similar visions and approached aerospace technology from a like-minded position, and while our on-orbit assets and data are different, together we bring unique and valuable capabilities to users.

Such engineering approach is definitely original in the aerospace industry and thus worth noting. For this reason, it is set out in more detail below.

4.5 Production System

Planet is fully vertically integrated, it operates all aspects of its business except launch [40]. The company uses an agile aerospace approach for the design of its satellites, mission control and operations systems, as well as the development of its web-based platform for imagery processing and delivery [62]. Below, the pillars of its engineering philosophy are addressed.

4.5.1 Supply Chain: Using Non-Aerospace Components

Planet Lab's satellites do not contain a single component directly sourced from the space industry [40]. Instead, they use commercial, off-the-shelf (COTS) components. Planet found out that efforts made by the consumer electronics industry to reduce price and schedule had resulted in an extraordinary component catalogue available to everybody. The startup is convinced that it is no longer required to develop a specialised ASIC (Application Specific Integrated Circuit) when nearly all electronic functionality is already available in catalogue parts [40].

For instance, Planet takes advantage of the tools developed to perform the heat transfer analysis on the latest Ford Diesel engine, the electronic design tools used for the PlayStation 4, or some of the electronic testing houses present in Northern California available to perform environmental tests for the consumer electronic industry [40].

Traditionally, the space industry has been proudly acting like a global R&D department, pushing the technology limits and enabling advanced technologies to be developed and then adapted to everyday usage. At some point though this seems to have been inverted. Today, it is the consumer electronics industry who is behind the massive miniaturisation of electronics and technology that is enabling Planet to produce remarkable capability in a 5-kg satellite.

4.5.2 Lessons Learnt from the Consumer Electronics Industry

Planet Labs reports investing significantly in the packaging and the miniaturisation of satellite capability [40]. Aiming to compress most of the capability of a traditional small satellite, its engineers accepted the challenge to create an ultra-high density microsatellite. To do that, they drew lessons from laptop PC (Personal Computer), tablet and smartphone industries. Putting some inevitably large components (like reaction wheels) aside, a Dove looks similar to those state-of-the-art consumer devices: printed circuit boards (PCBs) with a lot of layers, outstanding high density of surface mounted (SMT) electronics components, and hardly any internal cabling.

Planet remarks a trend not only towards further miniaturisation but also towards higher levels of integration, inspired by the levels of hyper-integration or shared resources in the automotive and electronics industries. Knowing that an effective integration or sharing resources among single components in a spacecraft is key to increasing the system's functionality and density, Planet has adopted this no-boxes approach: power supplies and other resources are shared by all instruments, radios or consuming elements.

As Planet Labs puts it, "Small parts make tough systems!" [40]. This summarises an additional benefit of this ultra-dense architecture: fundamental modes become higher (outside the operating regime) and stiffness is increased. Likewise, smaller busses lead to smaller, less complex payloads, which in turn reduce the team sizes, materials, costs and development timelines [40].

Planet follows the software team management motto "*release early, release often*". This means small iterative steps and early customer engaging. And, in this case, is literally reflected in the startup's continuous cadence of launches. One complete iteration of a Dove satellite takes 8 to 12 weeks from design to manufacturing [40]. Most importantly, this prevents obsolescence by continuously integrating the latest technology improvements. Chester Gillmore, Planet's director of manufacturing, explains, "We're building satellites with computers that are six months old. Lots of satellites have 10-year-old computers". Also, the iterative process is continuously improved: Gillmore estimated version no. 9 of Doves cost around 35 percent less than the no. 7 and was completed four times faster [70].

4.5.3 The New Agile Aerospace Philosophy

The agile development methods applied by Planet Labs are enabling its unusually rapid design lifecycle. This is an approach to software development extended in Silicon Valley, but Planet Labs is applying it to its hardware development too. It is what they call "building hardware as if it were software" [40]. Among others, it includes:

- Learning as the primary goal and success metric
- Building over documenting ("well-written code is its own documentation")
- User-centered design with early customer collaboration
- Respond to change over planning, in order to avoid fixing items out of the critical path. This allows distributing risk throughout the system and among stakeholders.

4.5.4 Space Testing

In the design of its first constellation (Flock 1), Planet Labs avoided the laborious process of developing a comprehensive thermal model. Instead, the company "relied on engineering best practices" [40]. The idea seems bold but turns out very sensible. Instead of putting a lot of effort into building the best possible version of a spacecraft (which has always a long way to go), why not send just an MVP (Minimum Viable Product), wait to see how things go—while learning—and do it better the next time. After all, we cannot send humans to Mars using only a first iteration of calculations, but when launching a nanosatellite to VLEO one can dare to take some risks—and maybe *should* do it. In fact, “This in-situ information is clearly better than any on-the-ground simulation, and is a great use of *build a little, test a little*”, Planet’s CEO remarks [40]. Besides, this approach allows learning more lessons faster than it would be possible through analysis and ground testing.

4.5.5 Distributed Risk

Even if the satellites you build are the size of a loaf of bread, "It's a risky business going into space, which we've experienced. We've had 10 launches, two of which exploded. One was the Antares rocket and one was the SpaceX rocket. We had 26 satellites on one and six satellites on the other and yeah, that sent our satellites to smithereens”, CEO Will Marshall admitted.

However, as Marshall points out, the startup was smart enough to put just a limited amount of its satellites in each of those launches [39]. Planet fosters a culture of risk tolerance and failure acceptance. Embracing risk means managing risk, which is basically done by distributing it.

Planet Labs has an original way of dealing with redundancy [40]:

> *“Rather than building redundant systems into a single satellite, which requires a larger team and more materials, thus higher costs, we build redundancy into the overall constellation. This puts the cost burden on the production rather than R&D, which is proportionally less expensive”.*

The company allows for a part of its satellites to fail, and designs the constellation taking that into account. In my opinion this similar to the engine-out design rule in aeronautics: engineers design each aircraft as if one engine was to fail during takeoff. In Planet’s case, this approach provides reduced development times and results in an overall risk reduction. And it has the additional benefit of allowing A/B testing. Putting different satellite variants across the constellation is a good practice to keep improving the technology used without risking the whole mission [2], and it enhances adaptability to change [40].

This capability to respond to market shifts helps Planet amortise its satellites over shorter lifetimes, which is the reason why it is economically feasible for the startup to build its constellation in VLEO.

4.6 Operations and the Pipeline

Planet Labs utilises a fully automated data pipeline that is designed to manage heavy data loads from a target fleet of up to 150 satellites operating in a constant monitoring mode. It use two low-speed UHF systems for spacecraft operations and high-speed X-band system for downloading the imagery files.

The startup has developed its own network of 30 ground stations, located in the US, UK, New Zealand, Germany and Australia. This network has been designed to ensure both efficient mission operations and successful downlink of imagery data. Each of those ground stations consists of an antenna and a Radio Frequency (RF) system, supported by a local computer server, connected to centralised services via secured VPN (Virtual Private Network) access. Downlinked imagery is transferred from the local ground station servers to the company's cloud infrastructure. From there, it is introduced into Planet's data processing and distribution pipeline to finally be delivered to customers [72]. Figure 11 depicts this end-to-end data flow.

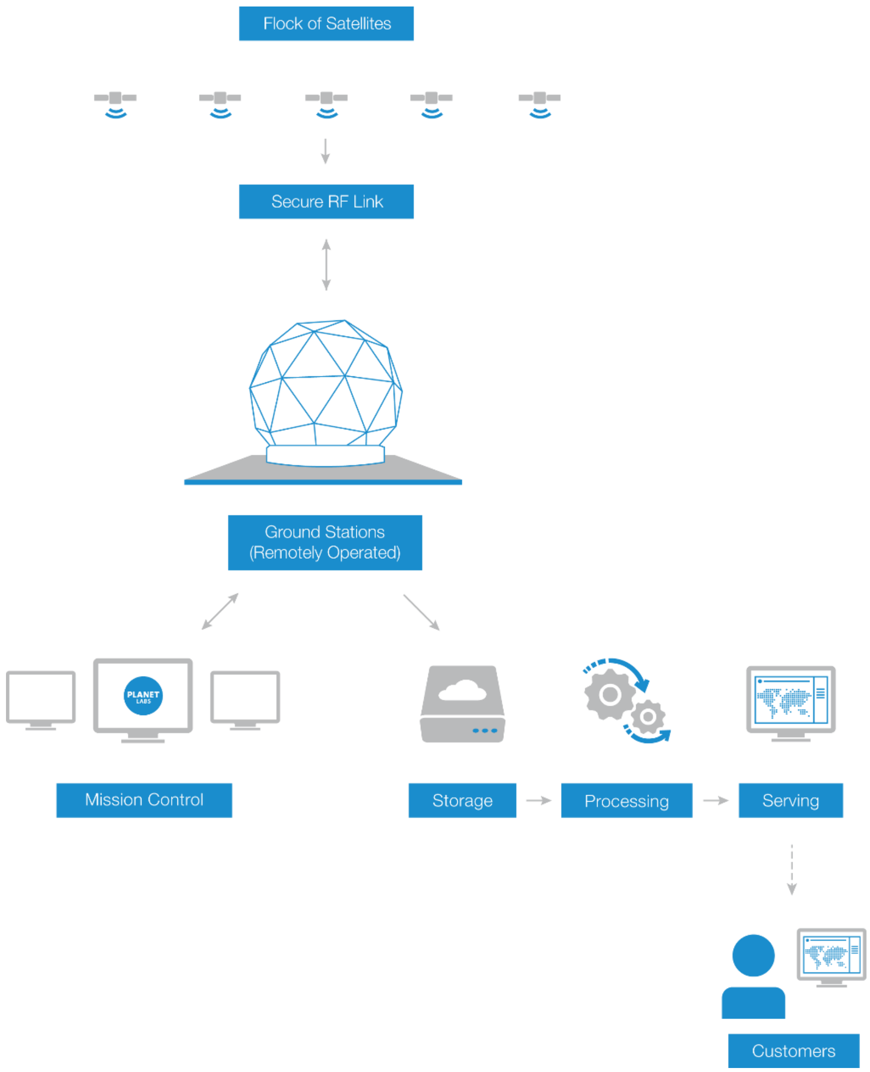

Figure 11 End-to-end data flow. Source: [72]

Such infrastructure will allow to collect and process 11 terabytes of imagery data every day [73]. All those image files will be available to customers within 24 hours from capture through the company's web product.

A good illustration of the high degree of automatization of Planet's operations is an incident that once took place. Two of their satellites got deployed overnight in a completely unscheduled deployment from the ISS. No one was on duty. The team went to work the following morning and just found a new pair of Doves on their screens. They had successfully commissioned themselves and started contacting the ground stations. Will Marshall says this is how Planet–accidentally—became the first company to commission a satellite (actually two) "without anyone in the loop" [39].

4.7 Applications and Customers

Planet’s satellites are not tasked with searching for particular images; their *Mission 1* (as Planet puts it) is to scan the whole Earth every day. Customers can then search for the images they want using GPS coordinates.

A spatial resolution of 3–5 m and a daily revisit time, along with the global scanning mission, make possible for Planet’s imagery to track everything from crop yields to the evolution of Syrian refugee camps. The company does remark, however, that its products can be especially helpful for climate change monitoring [74]. Fighting deforestation has always been the founders’ favourite application: “The use case that inspires me the most is deforestation”, Marshall specified [75].

Figure 12 Planet's image of Zaatari Refugee Camp in February 2016. Source: [76]

This monitoring approach instead of a more traditional tasking one is translated into always-on operations that allow what Planet calls “catching serendipitous events”. That is exactly what happened in the summer of 2014 when its satellites randomly captured images of a just-starting forest fire in southern California [77].

One of the objectives of the constant monitoring mission is to be able to report changes on the Earth mass land. A probably unforeseen application of this took place around the 2015 earthquake in Nepal. Planet Lab's images, taken before and after the tragedy, revealed two remote towns no one was counting with. Aid workers could send in medical assistance and supplies. CEO Will Marshall considers this a success in his original mission to use space remote sensing to help people on Earth: "It was the first time our data actually helped people in the real world. Not just some sort of Silicon Valley bubble of hypothetical, you know", he said [74].

Another of Planet's ambitions has always been to democratise access to data. When an earthquake struck Ecuador and a wildfire erupted in Alberta, the startup made their high-resolution imagery of those regions available under an open usage license [75].

Partly, the idea behind Planet's mission is that of building an all-seeing eye that supervises everything on our planet without missing a spot, with the ultimate goal to catch anyone doing something wrong in the act. Be it cutting a tree or illegally building in conflict zones. The Amazon Conservation Association, for example, used their satellite imagery to map illegal gold mines in Peru [75].

But the San Francisco-based startup also intends to make money by selling its products to commercial clients. Images tracking daily agricultural production across the world, mining output, ships movements or even the number of cars in Disneyland parking lot. Planet has currently over 100 customers, ranging from humanitarian organisations to giants of the agriculture business like Bayer Crop Science [74].

Some of Planet's commercial customers include the following [78] [73]:

- Geoplex (mapping and GIS systems company based in Australia)
- Descartes Labs (providing access to scientifically calibrated satellite imagery)
- Woolpert (US architecture, engineering and geospatial – AEG firm)
- The Geographic Planning Collaborative (GPC) group (first customer in the MENA – Middle East and North Africa region)
- ProGea Consulting (partnering with Planets to map Poland)
- SNET (Satellite Network, geo-satellite leader)
- C-CORE (Canadian remote sensing giant)

Planet's relationship with its customers is worth noting. The Silicon Valley-based firm emphasises to base its approach in agile development methods [40], which entails adopting the values outlined in the Agile Manifesto [79]. That includes *customer collaboration over contract negotiation.*

In 2014, then-CTO Chris Boshuizen explains [40] that they advocate for the idea that early customer engagement and collaboration reduces the time required to learn key lessons. It also lowers the risk in emerging markets as the company can build what the market is demanding. As he explains in the mentioned paper, this approach of user- centered design transforms end users from simple customers into producers, as their needs and knowledge of the market are integrated into the design process from the very beginning. In accordance with this understanding, Planet states it integrates customers into its development process, which it claims to be more cost effective than investing in contract negotiation.

4.8 Values and Brand

Planet's goal is to use space to help life [80]. The *Planet Code of Ethics*, a means to put Planet's Company Values into practice, is shared on its website. The priorities mentioned are:

- Anti-corruption
- Follow international laws regarding global trade
- Preserve data privacy and confidentiality
- Maintain a positive work environment
- Perform a fair competition towards competitors
- Hire based on merits
- Avoid conflicts of interest
- Protect intellectual property
- Have a global positive impact on life on Earth and respect space

Planeteers really intend to achieve a breakthrough in the space industry, which they considers stuck in inefficient and unproductive old practices. They believe the current situation of space business calls for a more proactive attitude. From people like them who want to carve out a career in it, but also from everyone in the world. Co-founder and former CTO Chris Boshuizen states [42]:

> *"The space industry has been asleep for 30 years. I kind of feel like we're just waking up right now. I'd love to see more people starting companies in this space or similar spaces, just saying space entrepreneurship is back. I really want this company to not just show people what is changing about the world, but show them how they can help".*

This is what Planet's leaders call Global Sensing Revolution or Space 2.0 [39]. In a Sales Force conference [39], Will Marshall, asking for the aforementioned global collaboration, ends his speech posing an open question to his audience: “Imagine you had all these imagery data from the whole planet, then what would you do with them?” I believe that says something quite meaningful to anybody trying to understand Planet’s business model: it feels like the space startup had little concern about having a clearly identified ultimate use of its products; probably Planet’s leaders just believed that what they could do was something valuable in itself and decided to start doing it, with a firm conviction that applications would come alone. This is a smart idea, for it is not easy to foresee all the possibilities that could come before you even do that one thing that will change the game. It is interesting to see this approach of assuming risks, accepting possible failure and embracing challenge without guarantees reflected in its overall business approach, because it is the core of Planet’s engineering philosophy.

Regarding the startup’s branding, the first thing to note is that the firm’s name has been changed twice since its foundation in 2010 under the name of Cosmogia Inc. (Figure 13).

Cosmogia

Figure 13. Cosmogia original logo. Source: [81]

The company’s first satellite image was in fact released in 2013 under the name of Cosmogia (Figure 14).

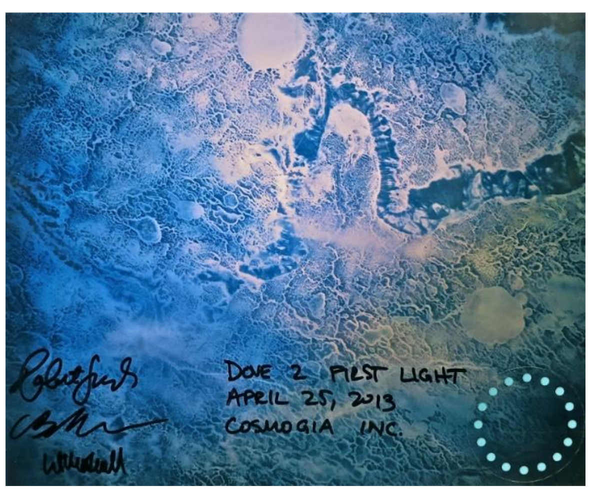

Figure 14 Cosmogia's first satellite image. Source: [82].

The corporation later changed its name to Planet Labs Inc., with the corresponding new logo (Figure 15).

Figure 15 Planet Labs logo. Source: [83].

Finally in the summer of 2016, a source reports the company shortening its name to just Planet [75]. The company has been referring to itself mostly as Planet ever since. Nevertheless, it still uses the *Planet Labs Inc*. signature on its official papers. This is a good example that can be interpreted as a sign of how the (still young) company is deliberately trying to keep a new, fresh and affordable image.

However, we shall not be mistaken for this effortless look. Carl Bass (former Autodesk CEO) who entered Planet's board in 2016, talked about it. "Planet is being very deliberate and careful as they build the company's culture, and they are moving very quickly", he said.

It is undeniable that Planeteers take care of little details they consider meaningful, like the fact that they called their satellites Doves because "they're on a peaceful mission" [39]. That is a statement about their vision, but also a playful gesture when they call their constellations "Flocks".

Tech writer Kevin Roose, who interviewed Planet's representatives at their headquarters in San Francisco, wrote: "If you haven't heard of them, it's because they've been avoiding most interviews with the media until they're further along in the development process." [58]. That is very true. When you perform a thorough search on Planet, you notice how, despite being founded in 2010 and successfully launching their first Doves in 2013, a good amount of publications arises in 2014, the year Will Marshall gave a TED talk [84]. While Planet is setting an example of uncertainty tolerance, it really feels like it has quite a lot of things under control.

4.9 Financial Status

According to venture capital research firm Pitchbook Inc., Planet was valued at about $1.1 billion after its last round of fundraising (in April 2015) [48]. Since then, the San Francisco–based startup has acquired BlackBridge (2015) and Terra Bella (2017), having the later been purchased by Google for $500 million the previous year [51].

Planet has been completely funded by venture capitalists in a series of funding rounds between 2013 and 2015. Altogether, it has raised $183.1 M.

Table 5 shows the amount raised in each round.

Table 5 Planet funding rounds details. Adapted from [85].

Funding Rounds - Total $183.1M				
Date	Round	Amount	Lead investor	Number of investors
Apr. 2015	Series C	$23M	IFC Venture Capital Group	5
Jan. 2015	Series C	$70M	Data Collective	17
Jan. 2015	Debt financing	$25M	Western Technology Investment	1
Dec. 2013	Series B	$52M	Yuri Milner	13
June 2013	Series A	$13.1M	–	7

Through these rounds, Planet has been funded from 23 different investors (see Table 6). They are some of the same investors who backed popular Silicon Valley companies like Facebook, Twitter and Tesla [58].

Table 6 Planet's VC investors. Adapted from [51].

Investor	Round(s)	Partner(s)
AME Cloud Ventures	Series B	-
	Series C	-
Capricorn Investment Group	Series A	-
	Series B	-
	Series C	-
Data Collective	Series A	-
	Series B	-
	Series C (Lead)	Zachary Bogue
DBL Investors	Series C	-
Draper Fisher Jurvetson (DFJ)	Series A	Steve Jurvetson
	Series B	Steve Jurvetson
	Series C	Steve Jurvetson
Dylan Taylor	Series C	-
Felicis Ventures	Series B	Renata Quintini
	Series C	Renata Quintini
FF Angel LLC	Series A	-
First Round	Series A	Rob Hayes
	Series B	Rob Hayes
	Series C	Rob Hayes
Founders Fund	Series B	-
	Series C	-
IFC Venture Capital Group	Series C (Lead)	-
Industry Ventures	Series B	-
	Series C	-
Innovation Endeavors	Series A	-
	Series B	-
	Series C	-
Jeff Seibert	Series C	-
Lux Capital	Series B	-
	Series C	-
Oreilly AlphaTech Ventures	Series A	-
	Series B	-
	Series C	-

Investor	Round(s)	Partner(s)
Ray Rothrock	Series B	-
	Series C	-
Space Angels	Series C	-
Syngenta Ventures	Series C	-
The Westly Group	Series C	-
Wayne Chang	Series C	-
Western Technology Investment	Debt Financing	-
Yuri Milner	Series B (Lead)	-
	Series C	

A little funding goes a long way in Planet. At least substantially more than in any regular space company. According to the company [40]:

> "A system of this scale would be extravagantly expensive if comprised of traditional satellite elements, yet we have attempted this with venture capital funding at a level that would be considered irrationally small by most aerospace standards".

While the startup will not disclose its manufacturing costs, potential customers who have seen the products feel that its Doves are about 95% [70] more inexpensive than most satellites. Mr Marshall would not comment on the figure, "We leverage the billions of dollars spent on the consumer mobile phone business for most of the company's parts", he said.

Since launch costs basically depend on spacecraft weight and orbit altitude, these are also lower than usual. Doves are so light that the 28 of them in Flock 1 weighed less than 60 kg on a launcher [70]. This means not only incomparably fewer kilogrammes than those in a 2-tonne Landsat, but also an adaptability that allows them to be contracted as secondary payloads, instead of requiring a more expensive dedicated launch. Likewise, Flocks are orbiting around 400 km above the Earth's surface, in contrast to the 700-kilometre altitude of Landsat satellites.

5. Case Study: DigitalGlobe

This chapter is the case study about DigitalGlobe and includes the same sections seen in Planet Labs' case study.

5.1 History and Company Overview

Back in the 1990s, the only satellite images that users could get hold of were the ones from the space programs that governments sponsored. That poor-resolution commercial imagery was not even a primary mission goal, but only a secondary benefit. At that time, professionals like civil engineers planning channels to control floods or geologists exploring sites for mineral exploitation could not even dream of having access, right from their personal computers, to a digital library of high-resolution Earth images taken from space. This milestone would come with the launch of IKONOS-2 satellite in 1999, which became the world's first commercial satellite to obtain panchromatic (black-and-white) imagery with sub-meter (0.8 m) resolution and multispectral (colour) images with 3.2 m resolution [86]. Symbolically enough, this imagery was first released on the first day of the twenty-first century [87].

However, before that dream could come true and DigitalGlobe could be a part of it, there would be much more to come. Some attempts would end in failure (EarlyBird-1, the company's first satellite, was launched in late 1997 but contact was lost four days later [88]) and quite a few company merging would be required (while DigitalGlobe operated IKONOS-2 during its last two years of service life, the spacecraft was initially operated by Space Imaging, later called GeoEye and finally purchased by DigitalGlobe). But first of all, it was the law that needed to be changed.

It was January 1992 when the company was founded in California by Dr Walter Scott as WorldView Imaging Corporation [89]. That was actually nine months before the U.S. Congress passed the Land Remote Sensing Policy Act which would allow U.S. private companies to enter the space remote-sensing business [89]. Entrepreneur Walter Scott was previously Program Leader of the Lawrence Livermore National Laboratory (LLNL) "Brilliant Pebbles" and "Brilliant Eyes" projects for the Strategic Defense Initiative. He was joined later that year by co-founder and initial CEO Doug Gerull, who was previously the executive responsible for the Geospatial and Mapping Sciences Division at Intergraph. Gerull would stay in WorldView until 2000 [90] before the remote sensing firm adopted its current name and launched its first successful satellite, which would only come with the third attempt.

One year after its foundation, WorldView Imaging Corporation became the first company to receive a high-resolution commercial remote sensing license from the U.S. government. In 1995, WorldView merged with Ball Aerospace's commercial remote sensing business, who brought communications and optics experience in satellites manufacturing. As a result of the merger, the enterprise became EarthWatch Inc. [91].

After its second satellite launched Quickbird-1 did not reach orbit due to a problem in the launcher in 2000, in September 2001 the company finally became DigitalGlobe [92]. One month into the renamed corporation's history, it launched its first successful satellite, Quickbird-2, built by Ball Aerospace and today usually referred to as just Quickbird.

In 2007 and aiming to increase its imagery distribution capabilities, DigitalGlobe purchased web-based satellite and aerial imagery provider GlobeXplorer [93]. In the following two years, the enterprise signed key agreements with customers like Microsoft, Nokia and Google. Those collaborations allowed DigitalGlobe to extend the reach of its products and services, enabling major mapping and LBS (Location-Based Service) applications featuring high-resolution satellite imagery [91].

While establishing those partnerships, the company also launched the first two satellites of its current constellation, WorldView-1 (September 2007) and Worldview-2 (October 2009), with 0.5-meter and 0.46-meter resolutions respectively and both weighing in excess of 2,000 kilogrammes [94]. That gained them the largest constellation collection capacity in the market [91]. Also in that period, the business went public (2009) [91].

During the 2010s, DigitalGlobe has kept growing at a good pace. It has strengthened its position in the industry by merging with existing firms. Most notably, it merged with GeoEye in 2013 and, according to DigitalGlobe, became a leader in satellite Earth imagery and geospatial analysis offering a wider range of products and services [91]. This is not only DigitalGlobe's opinion, it was also a temporary concern of the antitrust section of the U.S. Justice Department, who thought it gave DigitalGlobe a monopoly [95]. The transaction, which combined the two main providers of commercial satellite imagery to the U.S. government, took place after the U.S. National Geospatial-Intelligence Agency (NGA) announced that EnhancedView, the 10-year contract of $7.3 billion that the two companies were sharing, would be significantly cut, but only affecting GeoEye's part [96]. At the moment of merging, DigitalGlobe had two satellites, WorldView-1 and WorldView-2; the GeoEye acquisition added the IKONOS (previously referred to as IKONOS-2) and GeoEye-1 spacecraft to double its fleet. Similarly, it also acquired Spatial Energy in 2014, gaining geospatial solutions from different sources for Energy companies, and The Radiant Group in 2016 [91]. Also, the Colorado-based company has continued to launch satellites, WorldView-3 in 2014 and WorldView-4 (originally built as GeoEye-2) in 2016, the latter doubling the corporation's capacity to collect the market's best resolution –30 cm— imagery [91].

In February 2016, DigitalGlobe announced the formation of a joint venture with TAQNIA, a Saudi Arabian technology development firm, in partnership with KACST (King Abdulaziz City for Science and Technology) to develop a constellation of 6 or more small imaging satellites with an expected resolution of 0.8 m [97]. KACST will be responsible for building and launching the satellites and will commercialise half the obtained imagery capacity of the Middle East. The other half and the whole capacity of the rest of the world will belong to DigitalGlobe. Such small satellites would be scheduled for launch in 2018–2019 [98].

Today, DigitalGlobe owns and operates a fleet of 5 sharp-resolution satellites: WorldView-1, GeoEye-1, WorldView-2, WordView-3 and WorldView-4, with spatial resolutions between 0.31 and 0.5 m. The technological sophistication of its fleet, together with its 25-year expertise, indisputably places the public company among the top positions of the global commercial satellite imaging industry.

The latest chapter in DigitalGlobe's history opened in February 2017, when the company agreed to combine with MDA (MacDonald, Dettwiler and Associates Ltd.), a giant supplier of "space-based and airborne surveillance solutions, satellite ground stations, and associated geospatial information services" [99]. DigitalGlobe describes this as "an opportunity to create an integrated geospatial leader with end-to-end solutions" [100]. According to the agreement, the Canadian company will buy DigitalGlobe for US$2.4 billion in cash and stock and will assume DigitalGlobe's US$1.2 billion debt load [101] –US dollars are specified here to avoid confusion with Canadian dollars. DigitalGlobe will keep its name, brand and Colorado headquarters [99], and will become a subsidiary of SSL (Space Systems/Loral) MDA Holdings, the U.S. operating company of Canadian MDA [98].

MDA's acquisition of SSL (2012) and DigitalGlobe (2017) are part of the Canadian company's plans to boost its presence in the United States, with the ultimate goal of attracting more U.S. government business. As part of the effort, Howard Lance (a U.S. citizen) was named CEO of MDA in 2016.

5.2 Leadership and Employees

5.2.1 Leadership

The original founder, Dr Walter Scott, remains today in the company, although he is not its CEO. He is executive vice president, CTO (Chief Technical Officer) and executive leader of platform and services in DigitalGlobe.

The complete Management Team comprising 17 positions is depicted in Figure 16, created according to the information made available at [102]. The most prominent position in the firm is held by Jeffrey R. Tarr, who is the president and CEO. Timothy M. Hascall is COO (Chief Operations Officer) and Gary Ferrera is CFO (Chief Financial Officer).

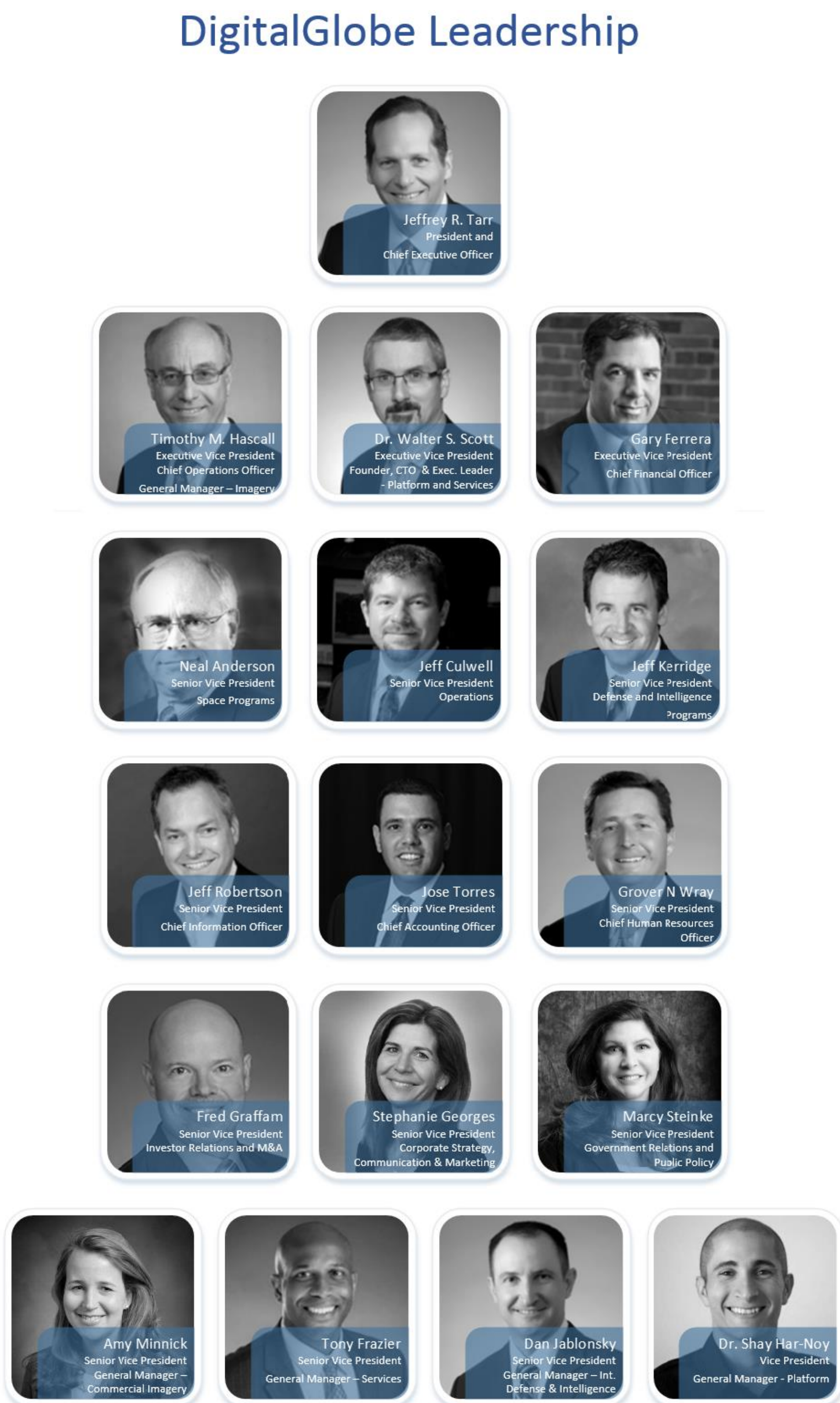

Figure 16 DigitalGlobe's Management Team. Author's composition using the information provided at [102]

5.2.2 Careers and Work Environment at DigitalGlobe

Today, DigitalGlobe has over 1300 employees scattered around the world [46]. Its headquarters are located in Westminster, Colorado but the company is extended across the United States from North California to Florida. It is also present in Canada (British Columbia and Ontario), South America (Chile and Brazil), Europe (Spain, UK, France, Italy and Denmark) and Asia (Russia, China, Japan, India, Thailand, Singapore and the United Arab Emirates). Finally, its offices in South Africa and Australia make the firm present on all the continents of the world.

On its website [46], DigitalGlobe highlights how many benefits its employees enjoy, from a professional development program to health insurance. In their reviews of the company [103], the workers particularly appreciate those, along with the efforts made by the firm to allow a good work-life balance despite the occasional heavy workload. Likewise, surveys completed by its employees gained DigitalGlobe the Top Workplaces prize by The Denver Post, which is shown at the top of DigitalGlobe's corporative web page. The following statement is displayed alongside it [46]:

> *DG is blue-chip solid. And start-up passionate. We are* ***right-sized*** *for employees to be heard* ***and*** *to have a real impact on our planet. (It's no wonder we received this award!)*

5.3 Products and Services

DigitalGlobe boasts about having the "sharpest resolution", "largest collection capacity", "unsurpassed haze penetration", "broadest spectral diversity", "best locational accuracy", "largest historical library", "unique cloud solutions" and "frequent revisit rate" [104].

The public satellite-imaging company does not make any information regarding temporal resolutions (allegedly its weak point) very easily available. Only somewhere [94] is it written that its satellite constellation has the "fastest 50 cm revisit times –intraday revisits." However, it is a fact that the company offers real high-resolution images with 30 cm per pixel side [104] that collects at a rate of 3M km^2 a day [105] or picks from a 16-year long archive.

DigitalGlobe focuses on a market segment that prioritises spatial resolution or image quality over temporal resolution. Assuming a daily revisit time, DigitalGlobe would be offering a data with just the required temporal resolution by most businesses to monitor economic activity, at a spatial resolution well above the economic scale, according to what analysts in this field have reported [4].

The raw images obtained by DigitalGlobe's satellite constellation are processed into different products to meet customer needs. According to a product catalogue of the company's satellite imagery [106], this imagery is delivered in product levels designed for three different uses:

- Image manipulation and photogrammetric analysis by image processing systems
- Image viewing and feature analysis in geographic information systems
- Image viewing and locational reference by users in any application

All of the satellite imagery products and their configurations are standardised for an easy ordering for the common market demands. Apart from these standardised products, DigitalGlobe is also offering customised services for customers requiring special configurations.

Selecting imagery for a product starts by defining an Area of Interest (AOI), which is the specific Earth area the customer is interested in. Given the AOI, the appropriate imagery is selected from DigitalGlobe's ImageLibrary if possible, or a new collection request is submitted otherwise (dedicated operational mode known as "tasking" the constellation). Such AOI, in turn, gives the sum of square kilometres of the product, which will be used as the base unit of measure for product pricing [106].

Customers placing a new collection request can choose between default and advanced options regarding prioritisation level, cloud cover and delivery, in addition to the start and end date of imagery acquisition.

Whether the customer finds the desired imagery in DigitalGlobe's archives or obtains it by a new collection request, it can be processed into multiple product options, as aforementioned. Product type and product configuration parameters are selected according to the intended use of the images. The product type has three value drivers: resolution (Table 7), spectral bands (Table 7) and product processing levels (Table 8). All three selectable items impact pricing. On the other hand, the product configuration parameters are usually customer-driven preferences which do not affect final price. Such parameters include resampling kernel, dynamic range adjustment (DRA), bit depth, datum and projection, tiling and format.

Table 7 shows the different resolutions and spectral bands available. Spatial resolutions are up to 0.3 m. Spectral bands available can be classified into 3 categories: panchromatic (1 band only, black and white), multispectral (4 or 8 multispectral bands) and pan-sharpened (an enhanced colour product with the visual information of the multispectral data and the spatial information of the pan data).

Table 7 Specifications options for Standard Imagery. Source: [24].

Product options		
	Pixel resolution*	**Image bands**
Panchromatic	30 cm, 40 cm, 50 cm, as collected	Panchromatic
Multispectral (4-band)*	1.2 m, 2 m, as collected	Blue, Green, Red, NIR1
Multispectral (8-band)	1.2 m, 2 m	Coastal, Blue, Green, Yellow, Red, Red Edge, NIR1, NIR2
Bundle (pan + 4-band)	30 cm, 40 cm, 50 cm, as collected	Panchromatic
	1.2 m, 2 m, as collected	Blue, Green, Red, NIR1
Bundle (pan + 8-band)	30 cm, 50 cm	Panchromatic
	1.2 m, 2 m	Coastal, Blue, Green, Yellow, Red, Red Edge, NIR1, NIR2
Natural Color	30 cm, 40 cm, 50 cm, as collected	Blue, Green, Red
Color Infrared	30 cm, 40 cm, 50 cm, as collected	Green, Red, NIR1
4-band Pan Sharpened	30 cm, 40 cm, 50 cm, as collected	Blue, Green, Red, NIR1

As Table 8 shows, the products are offered in various processing levels depending on the corrections applied, from basic product (only offered by DigitalGlobe) to engineered product (with the highest geo-positional accuracy and best aesthetics).

Table 8 Product catalogue overview. Source: [23].

PRODUCT NAME	PROCESSING LEVEL	DESCRIPTION	BENEFITS
System-Ready (Basic) **System-Ready Stereo (Basic)**	1B	DigitalGlobe's most basic product. Sensor corrected, un-projected (raw) product.	Ideal for 1) image manipulation and photogrammetric analysis by image processing systems. Only DigitalGlobe offers this raw level of product with rigorous model for orthorectification
View-Ready (Standard) OR2A **View-Ready Stereo (Standard) OR2A**	OR2A	Projected and resampled, projected to average base elevation. .	Ideal for 1) image manipulation and photogrammetric analysis by image processing systems, and 2) image viewing and feature analysis in geographic information systems
View-Ready (Standard) 2A	2A	Projected and resampled, coarse DEM applied.	Ideal for 2) image viewing and feature analysis in geographic information systems, and 3) image viewing by users in applications were location accuracy is NOT important.
Map-Ready (Ortho) 1:12,000	3D	High quality standardized orthorectified imagery Not available using Quickbird Catalog IDs	Ideal for 3) image viewing and locational reference by users in applications were location accuracy is important.
Map-Ready (Ortho) Engineered	3A – 3X	Highest quality built to order orthorectified imagery.	Ideal for 3) image viewing and locational reference by users requiring the highest degree of geo-positional accuracy or higher levels of aesthetics. Requires a custom feasibility analysis and additional price uplifts.

All of these technical variations of the products are made available under a number of commercial product lines, mentioned on DigitalGlobe's website [107]. Table 9 tries to classify and organise them taking into account the intended type of user (with varying levels of processing skills, and military). Relevant details given include additional descriptions provided by DigitalGlobe.

Table 9. Classification of DigitalGlobe's product lines. Created using information from [25].

Category	Product form	Relevant details
Imagery	Basic Imagery	For users with advanced processing capabilities.
	Standard Imagery	Georeferenced, ortho-ready imagery ready for processing, manipulation and data extraction. For remote sensing professionals.
Elevation Models	Stereo Imagery[6]	For users with advanced processing abilities to build their own elevation model.
	Advanced Elevation Series	Full-service elevation data. For users needing off-the-shelf elevation models.
	Vricon 3D and Elevation	Surface models, terrain models, point clouds and 3D visualisations available at scale, for network planning, line-of-sight analysis and situational awareness. For defence customers and extractive industries.
Datasets	Precision Aerial	To complement satellite imagery. For mapping applications that need consistency and completeness.
	SWIR	Short-wave infrared imagery. For applications in agriculture, forestry, mining and more.
	Human Landscape	Comprehensive human geography data in an analyst-ready format. For knowledgeable GIS professionals.
	Direct Access Program	Priority imagery for a dedicated purpose (tasking). For select defence and intelligence customers.

[6] I put Stereo Imagery under the Elevation Models category because it is intended for that use.

The company offers different access solutions for its products [107]:

- Basemap (user-friendly, for all users)
- FirstLook (for emergency service providers)
- GBDX Platform (DigitalGlobe's Geospatial Big Data platform, for GIS developers)
- Maps API (for developers of location-enabled applications)
- Spatial on Demand (for energy industry experts)
- EnhancedView (for authorised U.S. government personnel)
- Image Connect (desktop extension)

In addition to these products, DigitalGlobe also provides its customers with value-added solutions. The company points out [107] its expertise in the following:

- Analysis reports (predictive reports for business, market, environmental, political and military activities)
- Analytic services (location-based risk predictions)
- Crowdsourcing (leveraging thousands of imagery analysts)
- Human landscape (for expert GIS professionals)
- Marine services (for open-ocean sea fisheries)

5.4 The Satellites and the Constellation

The fleet owned and operated by DigitalGlobe is comprised of 5 sophisticated satellites at operational altitudes roughly between 500 and 800 km [94] (more or less typical LEO altitudes), all in sun-synchronous orbits. Aside from GeoEye-1 (which was originally owned by GeoEye, as explained in the History and Company Overview section), all of the spacecraft weigh in excess of 2,000 kg and are the size of a van (5.7 x 2.5 m for WorldView-3 for instance).

Besides, the Longmont-based company owns the digital library of two retired satellites, IKONOS (1999–2015) and QuickBird (2001–2014), which acquired 408 and 636 millions of square kilometres, respectively. That equals more or less 3 times and 4 times the world's land surface area [94].

For the purpose of clarification, let us summarise here that satellites owned by DigitalGlobe from the very beginning are: EarlyBird-1 (failed in 1997), QuickBird-1 (failed in 2000), QuickBird (originally named QuickBird-2, retired), WorldView-1, WorldView-2 and WorldView-3. On the other hand, IKONOS and GeoEye-1 previously belonged to GeoEye, like WorldView-4, which was being built as GeoEye-2 by the time of the acquisition. All seven satellites have been launched from the Vandenberg Air Force Base, in the U.S. [108].

Despite DigitalGlobe operating them as a constellation, those spacecraft do not share a common design. Figure 17 shows seven images that are reproduced with kind permission of European Space Imaging to show the overall design of the seven satellites owned by DigitalGlobe. Retired QuickBird (top row, left) and IKONOS (top row, centre) are also included to show the similarities between QuickBird and WorldView-1 (bottom row, far left), the first and second satellites originally owned by DigitalGlobe. Of the five operational ones, only WorldView-2 and WorldView-3 look alike, with the same layout of solar panels than WorldView-1 (a row of three panels at both sides of the satellite body); GeoEye-1 has all of its solar panels in a row, while the newest of the satellites has its solar panels displayed in star shape.

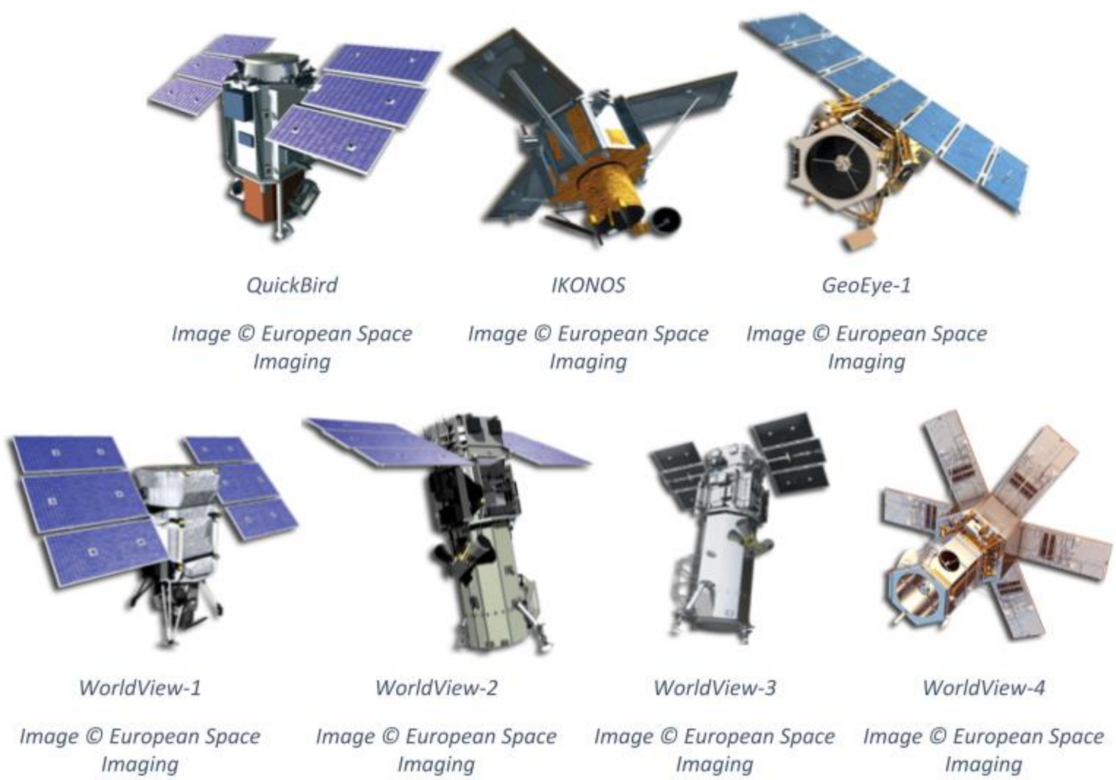

Figure 17 Collection of artistic renderings of DigitalGlobe satellites. Adapted. Original source: European Space Imaging.

Table 10 lists the specifications of each of the 5 satellites in the current constellation. Note how GeoEye-1 is somewhat different from the rest; not only is it lighter, it also has the highest revisit time, is the only using reaction wheels, has half the onboard storage and a slightly lower wideband data downlink rate. By contrast WorldView-4, despite being originally built as GeoEye-2, has very similar specifications to WorldView-3.

Table 10 Specifications of the operational satellites in DigitalGlobe constellation. Source: data extracted primarily from [9], complemented with launch and operating dates from [27].

	WorldView-1	GeoEye-1	WorldView-2	WorldView -3	WorldView-4
Launch date	2007	2008	2009	2014	2016
Expected operational life time	13	10	13	12	7
Operational altitude	496 km	681 km	770 km	617 km	617 km
Spectral characteristics	Pan	Pan 4 MS	Pan 8MS	Pan 8 MS	Pan 4 MS
Panchromatic resolution (nadir)	0.50 m	0.41 m	0.46 m	0.31 m	0.31 m
Multispectral resolution (nadir)	N/A	1.64 m	1.85 m	1.24 m	1.24 m
Accuracy specification (nadir)	6.5 m CE90	3 m CE90	6.5 m CE90	3.5 m CE90	4 m CE90
Average revisit at 40º N latitude	1.7 days	< 3 days	1.1 days	1.0 day	1.0 day
Weight class	2,500 kg	1,955 kg	2,800 kg	2,800 kg	2,600 kg
Attitude control actuators	Control Moment	Reaction Wheels	Control Moment	Control Moment	Control Moment
Onboard storage	2,199 Gbits	1,000 Gbits	2,199 Gbits	2,199 Gbits	3,200 Gbits
Wideband data downlink rate	800 Mbps total	740 Mbps total	800 Mbps total	800 or 1200 Mbps total	800 Mbps total

As previously pointed out (see History and Company Overview, page 49), DigitalGlobe plans to expand its fleet by 2018–2019 with at least six small satellites built by a partnership with the government of Saudi Arabia, which is a Direct Access Partner. Such smaller-satellite system, called Scout, will have a resolution of 0.8 m and would be operated as a complementary constellation used to spot potential interesting targets and then call the higher-resolution primary constellation [109].

In addition, WorldView-1 and WorldView-2 satellites are planned to be replaced by a next-generation satellite constellation named *WorldView-Legion*, to be launched in 2020 [101]. More details regarding the economic aspects of this plans can be found in the Financial Status section, page 68.

5.5 Production System

DigitalGlobe has always outsourced the manufacture of its satellites. Its past and present satellites were built by Ball Aerospace (QuickBird, WorldView-1, WorldView-2 and WorldView-3), Lockheed Martin (IKONOS and WorldView-4) and General Dynamics (GeoEye-1) in Colorado, California and Arizona, respectively. Note nevertheless, that all of the satellites originally belonging to DigitalGlobe have indeed been manufactured by Ball Aerospace alone.

DigitalGlobe has teamed with a long list of industry leaders in various segments of the value chain, namely the production segment, the ground segment and the space segment. It has also outsourced internal business systems, e-commerce solutions, other software solutions and systems engineering [110]. Below is a roster of some of DigitalGlobe WorldView engineering and co-production partners, extracted from a press release [111]:

- AERO-METRIC -- Co-Production and Data Provider
- BAE SYSTEMS -- Production Segment Integrator and Co-Production Lead
- Ball Aerospace & Technologies Corp. -- Spacecraft Developer and Integrator
- Boeing Launch Services -- Launch Services Provider
- Boeing Space and Intelligence Systems -- Engineering Service Provider and Co-Production
- EarthData International -- Co-Production and Data Provider
- Environmental Systems Research Institute, Inc. -- Co-Production
- Harris Corporation -- Satellite Command and Control System, Production Segment Developer, and Co-Production

- IBM -- Computing Hardware, Engineering Services, and ERP System Integrator
- InSequence -- Systems Engineering Services
- IONIC -- GIS Software and Engineering Support
- MacDonald, Dettwiler and Associates Ltd. (MDA)-- Production Segment Developer
- NASA Jet Propulsion Lab (JPL) -- Orbit Determination Tools and Support
- Observera -- Planning Services for Calibrations
- PRA -- Spectral Algorithms and Engineering Services
- RT Logic -- Satellite Interfaces and Control
- SAP -- Collaborative Business Solutions Provider
- ViaSat -- Ground Antennas

MDA’s purchase of DigitalGlobe will, however, change this outsourced production system. As a result of the combination, the Canadian company will become an end-to-end space contractor, building satellites, developing communications and offering surveillance services, according to Howard Lance, MDA’s president and CEO [101].

MDA’s Space System/Loral division, headquartered in Silicon Valley, will be responsible for building the future WorldView-Legion satellites in Palo Alto, California. According to Jeffrey R Tarr, DigitalGlobe president and CEO, this will help DigitalGlobe fulfil its financial objective to reduce its capital intensity (see section Financial Status in page 68 for more details). “One of the important aspects of this combination is access to SSL’s very advanced manufacturing capability and technology, and we believe that will contribute to reducing the capital intensity of the business”, Tarr said [101].

Once best known for its high-power geostationary communications satellites, today SSL has expanded the capabilities of its manufacturing centre to building smaller, LEO imaging satellites. This happened when the Palo Alto–based company was contracted by Terra Bella (then Skybox Imaging) in 2014 to build 13 small Earth-imaging satellites of its SkySat series [112]. Those satellites were based on a Skybox design and weighed about 120 kilogrammes each. However, under the terms of the contract, Terra Bella (bought by Planet Labs in 2017) granted SSL “an exclusive license to the satellite design”, according to SSL [112] or at least “certain intellectual property rights regarding its satellite design”, like Anusuya Datta, Executive Editor of Geospatial World publication [113] and other authors [101] report.

To whatever extend, this allowed SSL to apply the know-how and technology to other small satellites. And, while DigitalGlobe has not wanted to reveal many details about its planned WorldView-Legion constellation, including the size of the satellites or the size of the constellation itself, some journalists advance [101] that SSL's new expertise in small satellite manufacturing finally be leveraged to build DigitalGlobe's next-generation satellite system.

5.6 Operations and Delivery

DigitalGlobe's Mission Operations Centre is supported by "highly automated systems" [114]. However, it is not fully automated, as it also counts with teams of four knowledgeable satellite operators working all day every day to fulfil thousands of tasking requests per day [114].

The system collects more than 2,400 images every day (3 to 4 million square kilometres of Earth surface area), summing 70 terabytes per day to an image library of already 100 petabytes [114]. This is achieved through a global network of Remote Ground Terminals (RGTs) operated by the company. For security reasons, DigitalGlobe will not disclose the locations of those RGTs [115]

Since 2006 MDA, the global communications and information company, has partnered with DigitalGlobe to develop and deploy WorldView ground stations solutions into existing customer systems around the world [116]. In late 2015, the two companies signed a multi-million dollar contract for MDA to provide a large number of international ground stations with upgrades in order to receive and process imagery also from WorldView-4, the company's latest satellite which would be launched the following year.

Such upgrades in MDA's net of mobile and fixed ground stations would also give DigitalGlobe's customers the possibility to access and process near real-time data from RADARSAT-2 [116], a SAR (Synthetic Aperture Radar) owned and operated by MDA. DigitalGlobe also offers its customers access to Landsat imagery and high-resolution electro-optical and radar satellite imagery from other commercial providers [114], for an integrated source of satellite remote sensing capabilities.

Imagery received at an RGT is sent to the company's headquarters in Longmont, be it over the Internet or via a dedicated satellite link. There, it is decrypted and processed before it can be delivered to the customers. Delivery methods include media delivery (via DVD or external hard drive) [117], direct download and web platforms (like Global EGD and My DigitalGlobe); alternatively, it can be hosted in the cloud for analytic processing, using the company's Geospatial Big Data platform (GBDX) [114]. All in all, images get to the customers in between 12 minutes and 2 hours [114].

5.7 Applications and Customers

In October 2015 Peter B. de Selding from digital publication SpaceNews wrote that, according to the company's financial results and the information just presented by CEO Jeffrey R Tarr and CFO Gary Ferrara in a conference call with investors, "Westminster, Colorado-based DigitalGlobe is a tale of two very different enterprises." [118]. In the article, the author referred to the dramatically different levels of success achieved by DigitalGlobe on the two opposite sides of its business.

Its set of defence and intelligence customers, which is led by the NGA but includes other governments, represent a stable source of income. This is reflected in the EnhancedView contract with the NGA, which runs to August 2020 and represents DigitalGlobe's core business. On the commercial side of the business, however, the company did not obtain the expected growth after investing in specialised products for specific commercial vertical markets [118]. Nevertheless, Tarr denied that the company was losing competitions to other providers and asserted that the problem was the markets had not developed [118]. An additional reason is a decision made by DigitalGlobe to not offer its 30-centimeter imagery to Google Maps, as a way to protect this market advantage. This is how Tarr explained this in another conference call with investors in July 2015 [119]:

> *"Based on our first few months in the market with our 30-centimeter imagery, we've decided not to undermine our value proposition to customers in other verticals by selling our best imagery at too low a price to a segment that would make this unique offer freely available on the Web. (…) This strategic decision is the single biggest driver in the modulation of our near-term revenue expectations".*

As a response to the disappointing results, the company decided to scale back its investments in those commercial markets and revamp its commercial strategy, focusing on profitability and share repurchases to try to raise its stock price [118].

That strategy shift led DigitalGlobe to reinforce its relationships with its most reliable type of customers –governments. In the first quarter of 2016, the company reported a substantial growth in business from its 10 Direct Access Partner (DAP) governments and signed an initial agreement for an additional DAP customer. Such DAP customers have guaranteed access and distribution rights in their assigned region, plus local control of the company's fleet through their own ground stations. If a DAP customer exceeds its imagery quota, any additional data is billed at very profitable rates for DigitalGlobe. This is what has happened to some DAP customers in regions with geopolitical tensions like the Middle East and the Asia-Pacific [120]. For that matter, DigitalGlobe is confident it would be able to serve up to 15 DAP partners as long as they are not concentrated in the regions with higher demand, despite the company is already serving at its capacity limit even with WorldView-4 in service [120].

On its website [107], DigitalGlobe points out 8 different industries where its satellite imagery, data and analytics may be applied. These are:

- Civil government
- Energy
- Global development[7]
- Location-based services
- Mining
- U.S. government
- Defence and Intelligence
- Additional industries (like marine, agriculture and insurance companies)

While the U.S. government remains DigitalGlobe's single-biggest customer, the company also counts with other buyers. Its client list includes:

- Some U.S. federal agencies like NASA [121] and the aforementioned U.S. Department of Defence's National Geospatial-Intelligence Agency (NGA) [122].
- Innovative tech companies like Facebook, UBER, Mapbox and Esri [123]. Moreover, Google Earth and Google Maps used to license most of their high-resolution satellite imagery from DigitalGlobe [124].
- Conservation organisations like the Amazon Conservation Team [125] or the Jane Goodall Institute [115].

[7] Focused on vital resources like food, water and energy to help preserve natural diversity, human health, and prosperity.

DigitalGlobe is committed to helping the humanitarian community in large-scale crisis [114]. For that purpose, in January 2017 it created the *Open Data Program* for disaster response, aiming to assist response efforts by providing timely, critical information. Pre- and post-event imagery will be released openly licensed for select natural disasters each year; besides, Tomnod, the company's crowdsourcing platform, will prioritise micro-tasking to expedite damage assessments [115]. This was the case of Hurricane Matthew, when imagery and the corresponding information extracted were used by organisations like the United Nations, the Red Cross and the Government of Haiti [114].

Concerning its relationship with customers, DigitalGlobe has created the *Committed to Customers* (C2C) program which, according to Stephanie Comfort (Senior Vice President Corporate Marketing/Communications/Strategy), helps the company "both bring the strategy to life as well as understand what the customers need" [126]. Through the C2C program, DigitalGlobe finds opportunities to collect the customers' opinions, for instance in the semi-annual C2C survey to the company's Customer Advisory Board. This feedback is valued by DigitalGlobe and used to make informed strategic decisions to try to improve the services provided.

5.8 Values and Brand

DigitalGlobe states that its purpose, vision and values extend into everything it does and guide the company: "From our strategy to our culture, as well as our commitment to helping our customers save lives, resources and time, we keep our Purpose, Vision, and Values top of mind" [127].

These is DigitalGlobe's business statement [127]. Its purpose statement is actually a registered trademark:

- **Purpose**
  Seeing a better world ®
  "By giving our customers the power to see the Earth clearly and in new ways, we enable them to make our world a better place."

- **Vision**
  "By 2020, be the indispensable source of information about our changing planet."

- **Values**
  "We are relentlessly committed to our customer and our purpose. Our values guide us as we help our customer save lives, resources, and time. We act with integrity, always. We treat people with respect in all dealings. We put mission and team before self. We inspire curiosity and harness innovation. Our results matter."

DigitalGlobe's brand is focused on quality. Moreover, it places great importance on not just doing things well, but on doing them better than anyone else. This feels like a remnant of the boldness that prompted Dr Walter Scott to found the company when the space remote-sensing business remained still unopened. Regardless of the evolution experienced by the space industry and the increased competitiveness, DigitalGlobe, the first private satellite-imagery company in the U.S., keeps its ambition intact.

This clearly shows in the company's Vision ("be the indispensable source of information"), but also in phrases like "DigitalGlobe is the world's leading provider of high-resolution Earth imagery, data and analysis" [105] and even "DigitalGlobe's satellite constellation is the best in the world" [128].

This quality is translated into a relationship of confidence with clients, which the company highlights in speeches [126] and slogans ("Answers You Can Trust", in large lettering on its corporative website [129]).

5.9 Financial Status

In its 2017 first quarter results, DigitalGlobe reports having delivered "solid first quarter results with significant revenue growth across all of our major business units." [130]. It states it as continued to advance in their main strategic areas, enhancing its *Imagery Leadership position* (with the Enhanced View SLA, its highest revenue quarter in its DAP business and a 10% revenue growth in its Commercial imagery business), its *Platform Leadership position* (with important growth in GBDX, its geospatial big data analytics platform), and its *Services Leadership* (driven by the acquisition of The Radiant Group and also DigitalGlobe's *USG* analytics services business).

It also reports being focused on "extending our technological lead while reducing our Capital Intensity" [130]. In this respect, the company reports starting to invest in WorldView-Legion, which, as explained in The Satellites and the Constellation section in page 59, is a next-generation satellite system to be launched in 2020 in order to replace the capacity of ageing WorldView-1 and WorldView-2. The entire spending program of WorldView-Legion (presumably including the spacecraft construction, launch, insurance and ground infrastructure) would cost no more than $600 million [130]. This is in accordance with the company's intention to reduce capital intensity since the two old satellites to be replaced cost a combined $900 million, and WorldView-3 alone cost $600 million, according to Jeffrey R Tarr [118].

As for the company's financial performance, it reports its revenue for Q1 2017 was $209.7 million, up 19.6% with respect to Q1 2016 (unless any other reference is given, all figures presented in this section are extracted from [130]. This overall revenue is split into the company's main customer groups:

- **U.S. government**, with revenue for the quarter of $138.3 million, up 25.4% compared to the prior year period. Although the EnhancedView SLA remains flat, the U.S. government value-added services revenue increased from $22.2 million to $50.2 million, mainly due to The Radiant Group acquisition, but also for the growth in DigitalGlobe's services business.
- **Diversified Commercial**, with revenue for the quarter of $71.4 million, up 9.7%. This comes primarily from sales of WorldView-4 imagery to some DAP customers and the company's Global Basemap product suite. In fact, the DAP customer group experienced record revenue as a result of multiple crises in the Middle East, as noted in the section.
- **Other Diversified Commercial**, whose revenue was $35.3 million, up 10.7%, primarily from increased interest in the Global Basemap product suite, again, and the Platform business.

DigitalGlobe's cost of revenue for 2017 first quarter was $61.3 million. **¡Error! No se encuentra el origen de la referencia.** shows how this total cost is split into its components for 2017's and 2016's first quarters. Note how labour and labour-related costs are not only the biggest cost, but they have been more than doubled since the previous year, considerably raising the total cost of revenue. A footnote in the original source adds that this is due to the expenses for employees related to the addition of the Radiant Group.

Table 11. Q1 cost of revenue components. Source: [50].

($ in millions)	Q1 2017	Q1 2016
Labor and labor-related costs*	$ 39.9	$ 18.0
Facilities, subcontracting and equipment costs	18.5	13.6
Consulting and professional fees	0.5	0.6
Other direct costs	2.4	2.3
Total	$ 61.3	$ 34.5

SG&A[8] expenses were $63.1 million for the same period. **¡Error! No se encuentra el origen de la referencia.** shows the components of this SG&A cost for Q1 2017 and also Q1 2016. Again, labour and labour-related costs are the most important cost; also, a footnote in the original source explains that the consulting and professional fees are primarily increased due to the merger with Radiant. It is also interesting to note that the cost of satellite insurance is relatively low[9].

Table 12. Q1 SG&A Components. Source: [50].

($ in millions)	Q1 2017	Q1 2016
Labor and labor-related costs	$ 33.6	$ 26.4
Consulting and professional fees*	17.5	5.8
Rent and facilities	3.2	4.3
Computer hardware and software	2.6	3.3
Satellite insurance	2.9	2.3
Other	3.3	4.3
Total	**$ 63.1**	**$ 46.4**

[8] Selling, General & Administrative. Expenses incurred to promote, sell and deliver the products and services, and to manage the company [138].

[9] A quick comparison [4] suggests that operating costs would be far lower for a space company in the US (among other countries) than for a company in a country with more restrictive laws like the United Kingdom.

The satellite-imaging company reported generating $17.8 million of free cash flow[10] for the same quarter (Q1 2017). Table 13 shows how this figure for free cash flow is computed from operating cash flow and capital expenditures.

Table 13 Free cash flow reconciliation for Q1 2017. Source: [50].

($ in millions)	Q1 2017
Operating Cash Flow	$ 38.7
Capital Expenditures	(20.9)
Free Cash Flow[(1)]	17.8

Table 14 allows to compare data from the 2017's first quarter to the same period in the prior year, and gives an overall look of the most recent complete fiscal year. In comparison, free cash flow generated throughout Q1 2017 is 14.8% lower than that through Q1 2016. DigitalGlobe attributes this to "lower cash flows provided by operations due to increased costs for WorldView-4, merger costs and higher incentive-based compensation payments compared to prior year, partially offset by a decrease in capital expenditures." [130].

Table 14 Free cash flow reconciliation for 2016. Source: [50]

($ in millions)	Q1 2016	Q2 2016	Q3 2016	Q4 2016	FY 2016
Operating Cash Flow	$ 59.5	$ 91.2	$ 66.4	$ 88.2	$ 305.3
Capital Expenditures	(38.6)	(47.2)	(69.0)	(37.2)	(192.0)
Free Cash Flow[(1)]	20.9	44.0	(2.6)	51.0	113.3
Repurchase of Common Stock	$ 60.9	$ 15.9	$ 9.6	$ 29.3	$ 115.7

[10] Free Cash Flow is defined as the result of Operating Cash Flow minus Capital Expenditures.

For the last five fiscal years, DigitalGlobe's revenue has remained fairly steady throughout quarters, although the fourth quarter has always given the best performance (see Figure 18).

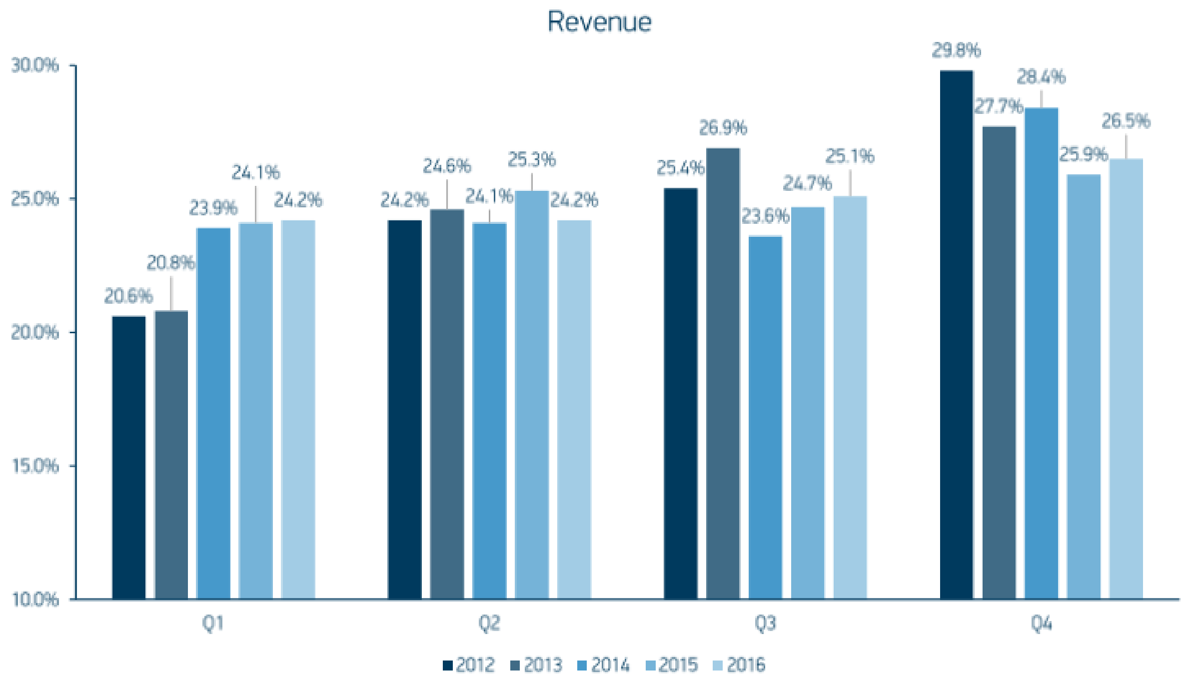

Figure 18 Historical revenue percentages by quarter from 2012 to 2016. Source: [131]

On the other hand, as Figure 19 shows, the company's net income has usually been more unstable for the first and the last quarters of the year.

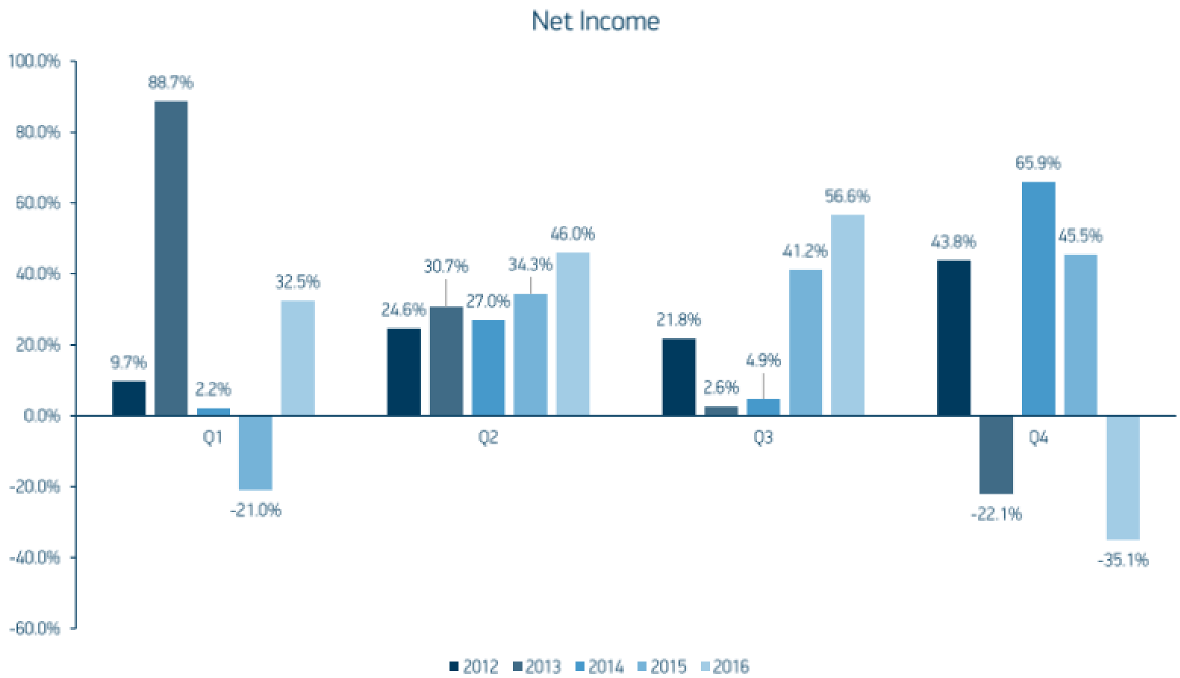

Figure 19 Historical of net income percentages by quarter from 2012 to 2016. Source: [131]

Regarding 2017 outlook, DigitalGlobe targets a revenue in the range of $840 million to $865 million. Besides, the company declared it will maintain its strategy for shareowner value creation. It will also focus on monetizing WorldView-4 and enhancing both its platform business and its combined services business.

Interestingly, the merger between DigitalGlobe and MDA will offer attractive vertical integration benefits, like reduced costs. Combining operations, as well as the possibility to leverage MDA's manufacturing capabilities, could save the joint entity between $50 million and $115 million per year [113].

6. Analysis of Business Models

This section addresses the target of the present study: to describe, compare and analyse DigitalGlobe's and Planet's Business Models. Unless any external reference is given, all the analysis presented here is my own.

6.1 Business Models Description

The Business Model Canvas (henceforth referred to as BMC or simply "Canvas"), designed by Alexander Osterwalder in 2008 and widely used by business professionals since then, is used in this study as a well-known standardised tool to document Business Models (BM). The Canvas, commonly used in business schools, is not a usual tool in engineering schools; however, I think it not only is a clear and powerful tool, but it also leverages some skills typically trained by engineers: the abstract thinking, allowing to see the big picture, and the logical thinking, to detect cause-and-effect relationships.

6.1.1 DigitalGlobe's Business Model Canvas

Figure 20 shows the Canvas for DigitalGlobe. The BMC follows a schematic design and is not intended to reflect all the reasoning behind the final output, but rather to achieve a simple look. To help the reader grasp some of the details behind this simple outcome, additional comments are given below. Notes of different colours are used (in the two Canvasses) to identify the elements belonging to different customer segments as well as the ones common to all of them (the latter, in blue).

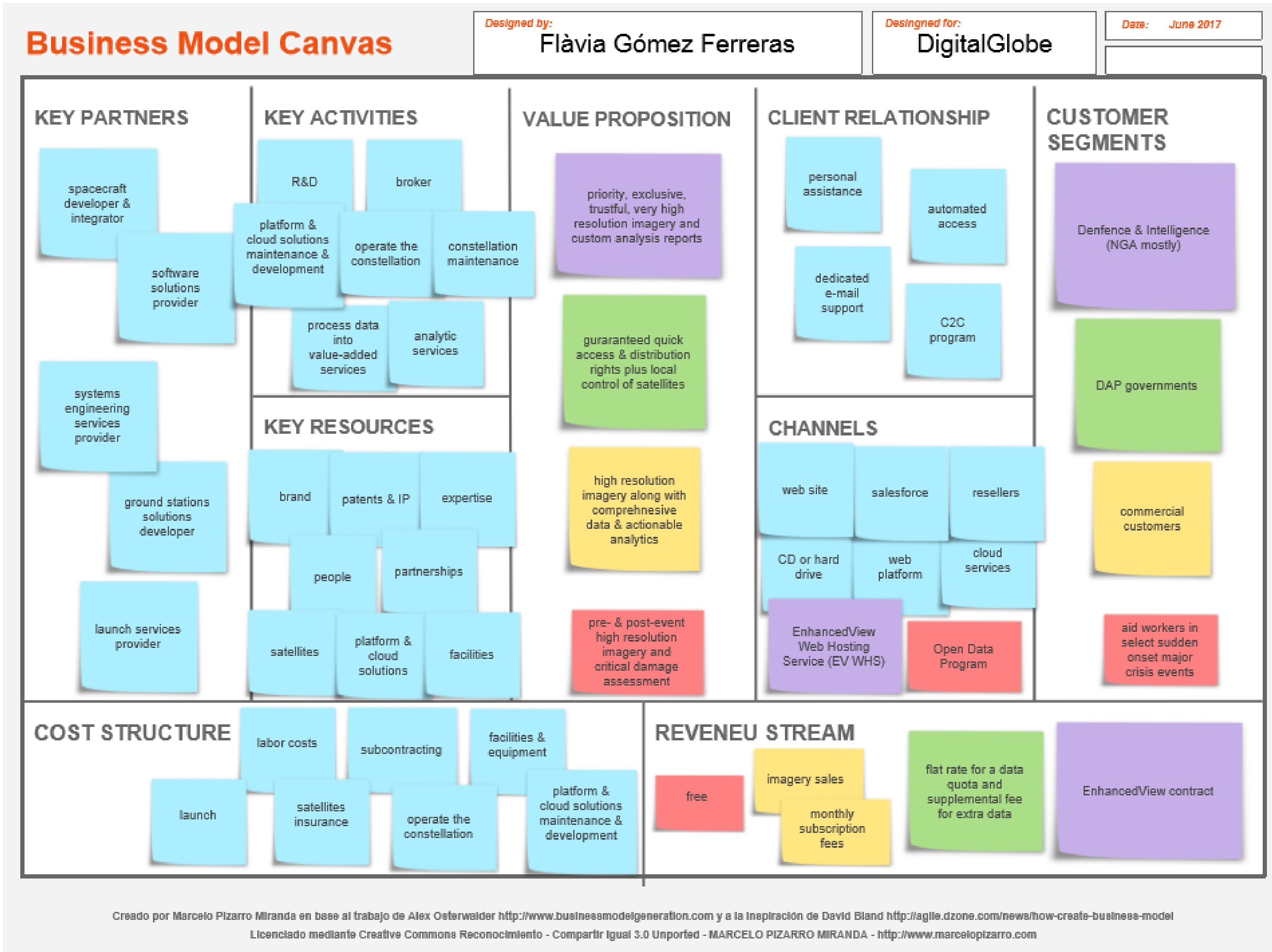

Figure 20. DigitalGlobe Business Model Canvas (own source).

Blue-coloured notes:

Notes in blue colour represent elements shared by all customer segments.

Key Partners: DigitalGlobe relies heavily on partnerships. It outsources a vast amount of activities in its value chain, from satellites manufacturing to software solutions (for satellite command and control, for example) or ground stations solutions. As stated in the case study, it partners with one only LSP (Launch Service Provider). As a minor detail not included in the Canvas, it has also received support from the JPL (Jet Propulsion Laboratory) for the orbit determination –this will gain relevance in the comparison between DigitalGlobe and Planet.

Key Activities: routine company activities include operating the constellation and of course working on the web platform and cloud solutions. As an enterprise with various partnerships and complex logistics, to mediate and manage all this is a key activity (broker). The value-added products and consulting services are also relevant and make this BM distinctive. Finally, the constellation maintenance activities are added to highlight the technical implications of a LEO constellation.

Key Resources: most key resources are intellectual (brand, patents and intellectual property, expertise and partnerships) and physical (satellites, web platforms and facilities). Brand and expertise are especially important because they are the reason for the trust that customers place in the company, which comes along with any of its value propositions. Also invaluable are partnerships, not only with suppliers or partners but also with customers (EnhancedView contract with NGA); this is the result of a long trajectory and brings business resilience.

Cost Structure: according to the latest financial details disclosed by DigitalGlobe [131], its biggest costs are related to labour (over 1,300 employees), subcontracting activities, facilities and equipment (including its Mission Operations Centre) and satellite insurance. Additionally, the launch is added to the Canvas as a non-recurring expense, albeit with a hefty price.

Client Relationship: DigitalGlobe's salesforce offers personal assistance to its customers, who later can automatically access the content through the platform. It also offers dedicated e-mail support to its bigger customers (startups, businesses and enterprises, as opposed to personal users) [132]. The aforementioned Committed to Customers (C2C) program enhances this relationship.

Channels: the corporative website is its main channel to inform its audience. Products are sold via the company's own sales force or by authorised resellers and delivered and stored in its web platform or cloud services in case further processing is desired.

Lilac-Coloured Notes:

Lilac notes relate to the biggest customer segment: Defence and Intelligence. This customer segment, primarily comprised by the NGA, is willing to pay for reliable, priority products and services with leading-edge performance. This is translated into the EnhancedView multi-year contract with the NGA, which constitutes the company's biggest revenue flow. This group uses a specific channel called EnhancedView Web Hosting Service (EV WHS).

Green-Coloured Notes:

These notes define the customer segment made up of the governments in the Direct Access Program (DAP). This customer segment enjoys a very particular value proposition: each DAP customer has guaranteed delivery speeds, access and distribution rights in its assigned area. Furthermore, it can even control DigitalGlobe's satellites from its own site. This means that the DAP customer can, with an hour in advance, reserve an access window and use its own ground station to directly upload the commands to the satellite and, likewise, later download the data. DigitalGlobe summarises this value proposition very well with the slogans "*Priority imagery at your command"* or *"Our constellation is your constellation"* [133]. This customer segment has also a different revenue stream which, as previously pointed out in the case study, is proving to be very profitable in the cases of customers in conflict zones, as any additional data requested by the DAP customer beyond a fixed quota is billed at a higher price.

Yellow-Coloured Notes:

Notes in yellow refer to DigitalGlobe's commercial customers. These are typically firms specialised in advanced image analysis for consulting services addressed at different industries, including energy, mining and agriculture (e.g. for precision agriculture). They may also be companies in the technology sector (primarily using location-based services). This customer segment is interested in the high-resolution imagery as well as the comprehensive data in the company's value-added products and the actionable analysis services from DigitalGlobe's consulting business. They may reach these products via DigitalGlobe's net of resellers, who can offer both subscriptions and one-time imagery sales, always with a fixed pricing mechanism; as explained in the case study, the price is product-feature dependent (resolution, spectral bands and product processing level) and volume dependent (Area Of Interest).

Red-Coloured Notes:

Elements in red represent a marginal customer segment, which is not considered relevant in DigitalGlobe's BM, but is included for the sake of completeness and impartiality, as will be seen in the comparison with Planet. DigitalGlobe's Open Data Program is meant to deliver pre- and post-event imagery of affected zones in "select" crisis events [133] at zero cost.

6.1.2 Planet's Business Model Canvas

Figure 21 shows Planet Lab's Canvas. An overall description of each of its 9 building blocks and additional comments are included below.

*Blue-Coloured Notes (*Figure 21*):*

Again, blue notes are common to all customer segments.

Key Partners: the company put it clearly, "Planet Labs is fully vertically integrated, operating all aspects of its business except launch" [40]. Bearing in mind that Planet's nanosatellites are launched as a secondary payload and sometimes deployed from the ISS (International Space Station), key partners include not only different LSPs but also space agencies and a company enabling to use the ISS as a commercial platform to deploy CubeSats (NanoRacks, in this case). Planet manufactures its own satellites, which means it partners with commercial off-the-shelf components suppliers, and, of course, relies on its investors.

Key Activities: R&D (Research and Development) activities in this BM are characterised by fast iterations (*release early, release often* motto*)*. This is what "agile aerospace R&D" means. The manufacture activities are hugely simplified by using a standardised form factor. On the other side, distributing risk among multiple and diverse launches (and launchers) requires thoughtfully arranging this segment. Planet tests primarily in space. It does perform some tests before the launch, but these are presumably reduced to the minimum required to assure the satellites will be able to withstand the launch stress loads. Space testing is rather an opportunity to perform A/B testing. Apart from routine maintenance activities regarding the Planet Platform (this is how the company calls its web-based platform), Planet operates its fleet, which requires only a minimum effort because of the completely automated pipeline. Much more attention demands the continuous process of rebuilding the constellation, and this includes not only restarting the build-and-launch loop but also to be aware of the degradation pace of the constellation. Finally, dissemination activities are included here to reflect all the conferences and interviews Planet has been giving to build its young brand.

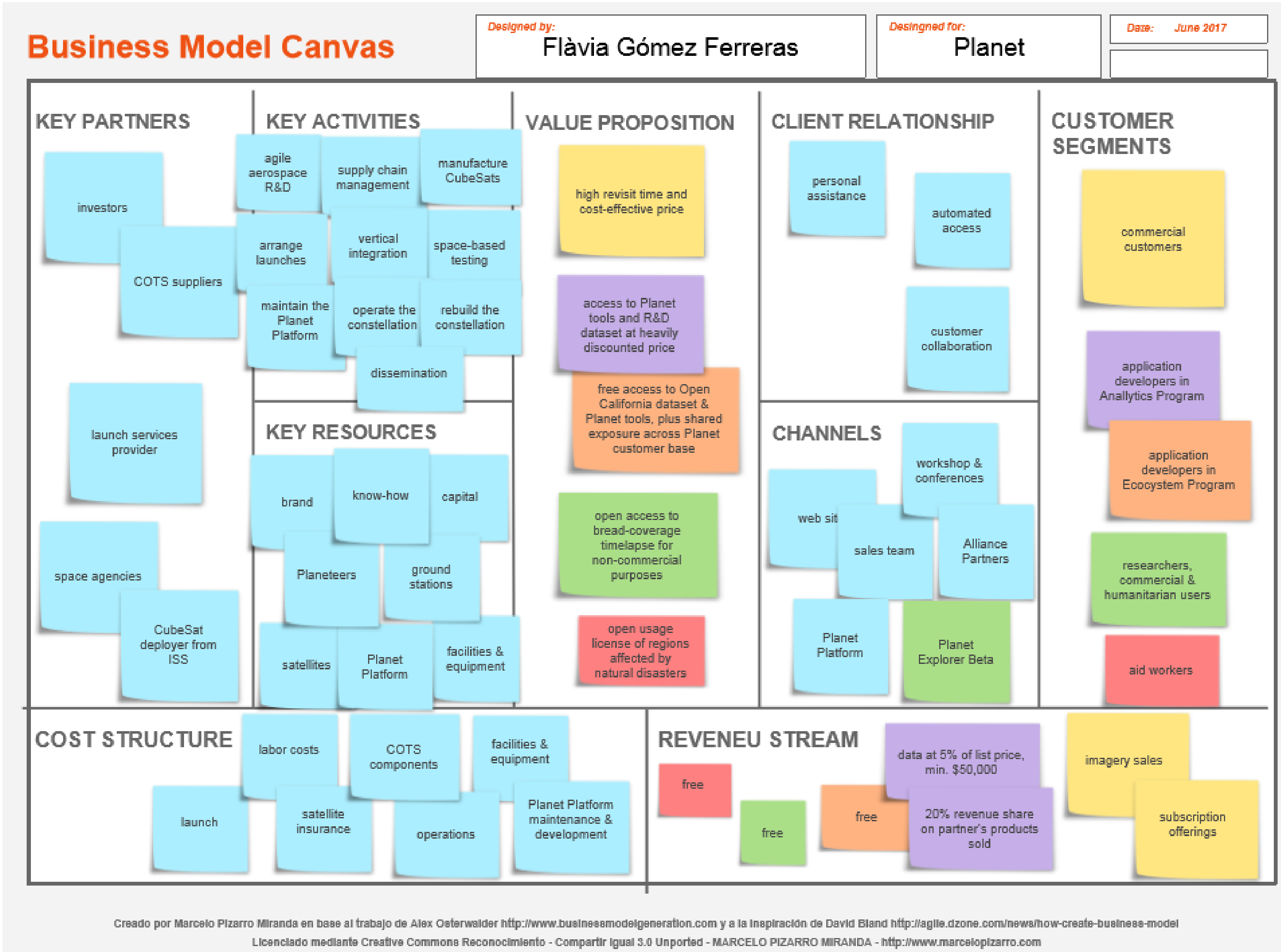

Figure 21. Planet Business Model Canvas (own source).

Key Resources: as a result of this carefully studied dissemination and branding, this young company (7 years old) has already created a well-known brand, and this is why it is included in the Canvas. Similarly, the rapid lifecycle and vertical integration approach have gained Planet "operational experience that is unique for such a young team" [40] –it is important to keep in mind that, instead of subcontracting a firm with experience in constellation operations, Planet risked to acquire this expertise itself using the *learning by doing* approach. This is the reasoning behind the "know-how" note, which does not include intellectual property and patents because Planet uses open-source software (OSS). All in all, Planet's Key Resources are not too much intellectual (brand and know-how) but rather physical (ground stations, satellites, Planet Platform, facilities and equipment).

Cost Structure: although Planet does not release detailed financial data, launch, salaries, facilities and equipment should be the most relevant costs. Launching as a secondary payload is cheaper but still costly; labour costs must be high in a company with so many knowledgeable engineers working in all phases of the process including software design; facilities and equipment are included too considering, for example, that the company's HD are in the trendiest neighbourhood in San Francisco or that the highly automated pipeline requires pricey IT systems, but note that its manufacturing facilities and equipment cannot be compared to those of a big-satellites company: *"Working from what he calls a "clean-ish room", separated from the kitchen by some loose plastic sheets"* [70].

COTS components, which Planet buys online [70], are a recurrent expense, but this type of components are specially chosen for its lower price [40], and the same applies to the fully automated operations. Dissemination is not regarded as a relevant cost because, as previously pointed out, it seems to be done by giving conferences and interviews, and neither of these would imply a cost. In this line, one would say that Planet is well aware that the best dissemination one can get is to do things so boldly differently that newspaper will come to report how rules and records are being broken –this happened on February 14, 2017, when mass media from all over the world wrote about Planet's 88-satellite launch.

Client Relationship: customers receive personal assistance and automated access to data while being engaged in a collaborative relationship.

Channels: workshops, conferences and interviews are used by Planet Labs to spread the word. Data and products are sold by Planet's sales team and its trusted resellers and distributors called Alliance Partners (e.g. Spanish INDRA S.A.). The Planet Platform is the main channel to access data.

Yellow-Coloured Notes:

Yellow elements define Planet's commercial customers. In the *freemium* business model pattern that Planet tilts towards, these commercial customers would be the paying users subsidising all the free users of the company (in green and red in this Canvas). Commercial customers might be interested in the high temporal resolution and/or the moderate price, and can choose from subscription offerings and occasional imagery sales, with the Earth land area and the timeliness as some pricing factors. These paying users may belong to different markets (defence & intelligence, finance & business intelligence, mapping, energy & infrastructure or forestry), although Planet's commercial customers nowadays relate mostly to agriculture –e.g. FarmersEdge, a consulting firm providing precision farming services.

Green- & Red-Coloured Notes:

These notes represent the non-paying target customers in the above mentioned *freemium* model. In green, the Planet Explorer Beta is currently offered for free as a platform to time-lapse global imagery at limited zoom (30–40 meter per pixel) and of the U.S. at full zoom (3–5 meter per pixel). This is targeted to researchers and humanitarian users, but also to commercial users, who might then get interested in acquiring data with higher resolution or with a commercial license, and shift into the paying customer segment. In a similar way, red notes refer to Planet's value proposition for aid workers in distressed areas when natural disasters occur, an application which is indeed aligned with Planet's mission to democratise access to remote-sensing data.

Lilac- & Orange-Coloured Notes:

These are explained in the last place because they follow a completely different idea. They must be split into two different customer segments according to BMC theory [134] because they have distinct value propositions and revenue streams. However, these two different partnership options offered in the Application Developer Program [135] can be described in the same manner. In line with the idea outlined in Planet's case study that points out how Planet does not seem hugely concerned about developing the far end of an end-to-end product, that is, building value-added applications on top of its satellite imagery or offering custom products or consulting services, the company uses these two customer segments to cover that need. As written in the case study, I believe Planet has not thoroughly identified—nor wants to do it—all the possible applications of its products. Knowing that some of these ends still have to be invented, it attracts application developers to develop value-added products that are fed with Planet's imagery data. This is an original value proposition (which includes joint marketing and sales efforts) for a customer segment that should be read not as a relevant source of income (like *commercial*, in yellow) nor a mission objective (like customer segments in green and red), but rather as an investment. If managed properly, in the future these Customer Segments should move from the far right to the far left side of the Canvas and become Key Partners, be it literally (Planet acquires their applications and sells them) or in a more indirect way (simply widening the range of uses, and markets, for Planet's offerings).

6.2 Business Models Comparison

Similarities

Looking at both Canvasses some similarities can be found at first sight, particularly in the blue and red notes. Actually, notice that notes in Key Activities, Key Resources, Cost Structure and Client Relationship building blocks that are equivalent in both Canvasses are placed exactly in the same position in the two documents for ease of comparison.

While the Key Partners building block is quite different, both companies outsource a crucial segment of the space system: launch segment. The two Key Resources blocks look quite alike, only changing partnerships (in DigitalGlobe) for ground stations (in Planet), expertise (in DigitalGlobe) for VC-raised capital (in Planet) and a subtle difference between "patents & IP" and "know-how". There are some common Key Activities as well: both are innovative companies with R&D departments, and, after all, operate a satellite constellation and manage a platform. Actually, the Channels building block shows that both companies use not only that web platform, but also web sales, a sales team and accredited resellers (no own nor partner stores). The Client Relationship is similar too, although DigitalGlobe seems to focus more on customer service while Planet establishes a more peer-to-peer communication. Finally, it is remarkable that, surprisingly, the Cost Structures present almost identical appearances (only subcontracting changes for COTS components).

Differences

Yes, the two Canvasses might present some similarities at first sight, but most of them are rather superficial and if we take a closer look, we can read the underlying opposed motives in every different decision.

Starting with the Cost Structure, although apparently, the only difference is in subcontracting versus buying COTS components, the truth is that this makes a huge difference, both in the business approach and the volume of costs. Furthermore, I would venture to say that each of those costs in DigitalGlobe's Canvas is notably higher than the one with the same name in Planet's. To put some examples, labour costs should be higher in DigitalGlobe (1,300 employees) than in Planet (300 employees); the degree of operations automatization is significantly higher in Planet[11], which would lower operations costs to a minimum; even the maintenance and development of the web platform and cloud services is supposedly higher for DigitalGlobe, who allegedly has first-class cloud solutions with huge capacity that it uses to store its vast archives acquired for many years.

Without sound data, it might not be easy to see what is more expensive, launching 5 big satellites or 200 nanosatellites. But we can do the math and see that the few big ones total 12,655 kg and the many tiny ones total 1,000 kg (a 2,000-kilogram satellite weighs as much as 400 CubeSats). Adding this to buying a dedicated launch (DigitalGlobe) versus flying as a secondary payload (Planet), maybe it really is possible to affirm that also launch costs are bigger for DigitalGlobe. And needless to say, the subcontracting costs in DigitalGlobe's Canvas (paying for a long list of items including state-of-the-art satellites) cannot be compared to the cost of buying COTS components online. Just like that, "*Perhaps the most important Planet innovation*", which is "*breaking the schedule and cost-cycles that the space industry is infamous for*" [40], might be illustrated.

[11] This is easily appreciated when contrasting pictures of DigitalGlobe's Mission Control Centre (with various teams of engineers) and Planet's Operations Centre (with one single person working in it).

Without question, the Key Partners building block holds key differences between the two companies. Planet's Canvas includes a few notes, but all of its partners either belong to the launch segment or provide raw resources (financial or material). All the rest of activities fall upon Planet Labs. Among those, there are a lot of arduous work packages that Planet is quietly doing. For instance, a number of differential drag experiments aimed at quantifying the phasing control authority and the ADCS (Attitude Determination and Control Subsystem) performance, which Planet had to do to be able to develop its differential drag algorithms that were to be used for phasing and station keeping[12]. This actually turned out more difficult than expected, for the company had to found out itself that the drag coefficient (C_d) for CubeSats was not well calculated for very low orbits [40]. This, which contrasts with DigitalGlobe more pragmatic option to use JPL's support, exemplifies the uncertainty that this approach implies. This is not the best option if the timing is the company's first priority, but is indeed aligned with Planet's philosophy, "*Learning is the primary goal and success metric of our missions"*[40]. Opposed to this, DigitalGlobe prefers to outsource a lot of activities. According to business experts [134], this is a way to reduce risk and uncertainty as well as optimise the allocation of resources and activities, leveraging the expertise and assets of a knowledgeable firm and taking advantage of economy of scale –in other words, if you want to have *the best constellation in the world* [128], asking a world-class firm like SSL to do it for you seems definitely more suitable than trying to do it yourself from scratch.

[12] Orbital manoeuvres required to keep a satellite in an assigned orbit, specially required when an additional satellite is added to the constellation and the previous satellites in the same orbiting plane must be reorganised to make room for it. Bigger satellites use small thrusters to do this, but Planet Labs' nanosatellites adjust their position to take advantage of the differential drag created on the opposite sides of the satellite to achieve the desired movement.

The previous explanation relates to the Key Partners, but also to the Key Activities. An interesting thought can be inferred from the later building block: Planet focuses on “doing everything” from individual satellite components to data downlink, but DigitalGlobe keeps working on the value chain after getting the data, adding value on top of the raw images and then adding problem-solving activities to generate final custom analytic services. Just to mention it, dissemination is included in Planet’s Canvas and not in DigitalGlobe’s in accordance with the amount and nature of the external communications found during the research phase of the case studies.

As already said, Key Resources are very similar for the two companies. However, the aforementioned subtle difference between “patents & IP” and “know-how” indicates indeed the opposed motives they have. DigitalGlobe is a well-known firm that has built up a substantial expertise and has experienced being a market leader and fighting and acquiring competitors; this fierce enterprise competitiveness might explain why it values intellectual property and partnerships. On the other hand, Planet has entered the market at a time when it was more open and has done it with a less competitive attitude –it does not seem worried about competing with others, like DigitalGlobe does when uses words like “most, best, highest, fastest”, instead it seems completely focused on completing its own “Mission1”. This, along with Planet’s preference for open source software, is why this *subtle* difference may not be so subtle. And, just to incorporate DigitalGlobe’s future plans to this analysis, let us remember its intention to reduce capital intensity, which is in line with the already absence of ground stations among its Key Resources.

Regarding blue notes (that means without considering the different customer segments and their respective value propositions and revenue streams), the four building blocks just covered (Cost Structure, Key Partners, Key Activities and Key Resources) present the most significant differences. Client Relationship and Channels, as already stated, present some minor variations but have the same core structure.

Analysing the blue notes on the two Canvasses, the foundations of both business models have been put forth and compared. These have explained: what the companies have (Key Resources), what they do (Key Activities), from whom they receive help (Key Partners), what they pay (Cost Structure), how they relate to customers (Client Relationship) and how they reach them (Channels). Now it is time to read and contrast the (coloured) VP-RS-CS lines (Value Proposition, Revenue Stream, Customer Segment).

The details about this have already been dissected in the description section. Now what is interesting is to zoom out and look at the big picture –in other words, not to compare only VPs, RSs and CSs, but the intention behind the global design. If done this way, it is quickly appreciated, first, that red elements define a line that is common to both business models. The only thing to mention here is that, while this value proposition fits in very well with Planet's stated intention of democratising access to EO data (and therefore with the rest of its business model), and although it does align with DigitalGlobe's stated purpose (*"…we enable them to make our world a better place*"), it does not really seem to fit in very naturally with the rest of its business model. Maybe it can be concluded that this offer appears more spontaneously in Planet's BM (because it seats closer to the green-coloured offer, the *free* in a *freemium* business model) whereas it is a more deliberate choice in DigitalGlobe's BM and would be located in a more peripheral location. Behind this idea there is also a small detail that differentiates Planet's and DigitalGlobe's statements about their respective offerings for aid workers: DigitalGlobe emphasises repeatedly that its Open Data Program is only opened in *select* cases [136], and the full history of covered events shows limited dates (January 2010, April and October 2015, April and October 2016, March and April 2017) [137].

The comparison of the rest of lines (coloured in lilac, green, yellow and orange in the Canvasses) can be summarised in the following terms: commercial customers (in yellow) act like a hinge between the two business models. In DigitalGlobe's Canvas, this customer segment, placed at the bottom, sets the limit of the least profitable customer segment and, from here, the company shifts its attention upwards, towards bigger, wealthier clients (this is backed by the company's recent declarations regarding its financial results and intentions, see case study). On the other hand, for Planet Labs, commercial customers, placed on top in its Canvas, constitute its most profitable customer segment, and in fact, allow the company to address the non-profitable customer segments below.

6.3 Additional Analysis in Terms of Business Model Patterns

Leading business thinkers have identified and defined some Business Model Patterns built on relevant concepts in the business literature [134]. Such Patterns show similar characteristics of the business model, similar arrangements of building blocks in a Canvas or similar behaviours of a company. Patterns are offered as a tool to understand business model dynamics and a source of inspiration.

In this section, Business Model Patterns are used to offer a supplemental analysis on Planet Labs' and DigitalGlobe's business models from a different perspective. The previous comprehensive analysis allowed to understand each BM. Now, this analysis will make it possible to put the two BMs in a wider framework and see how they compare to the rest of business models. The question posed is the following: do DigitalGlobe's and Planet's business models incorporate any (or many) known patterns?

In reference book *Business Model Generation* [134] there are five patterns explained. Planet's and DigitalGlobe's business models resemble 2 of them: *the freemium business model* and *the open business model*. Besides, there is a third pattern which provides interesting insights: *unbundling business models*.

The Freemium Business Model Pattern: Reach the Entire World

Definition of **freemium**[13] **business models** (extracted from [134]):

> Freemium stands for business models, mainly Web-based, that blend free basic services with paid premium services. The freemium model is characterized by a large user base benefiting from a free, no-strings-attached offer. Most of these users never become paying customers; only a small portion, usually less than 10 percent of all users, subscribe to the paid premium services. This small base of paying users subsidizes the free users. This is possible because of the low marginal cost of serving additional free users.

[13] The term "freemium" was coined by Jarid Lukin and popularised by venture capitalist Fred Wilson on his blog [134].

The two companies relate very differently to this pattern. It is not just that Planet inclines towards a freemium model (I use the verb *incline* because its business model seems to be still evolving, with the ongoing Application Developer Program), it also occurs that DigitalGlobe is opposite to it.

Freemium is just the right business model to meet Planet Lab's goal, democratising EO data. Its basic products can be made accessible to *everyone, everywhere, every day* (in Planet's words [40]) for free, as long as it also has products with greater performance or additional features that catch the interest of customers willing to pay more. Obviously, the business model will be profitable if the latter group pays not just *more*, but sufficiently more to subsidise the free customer base.

For the same precise reason, intention, the freemium pattern does not fit in with DigitalGlobe at all. Freemium implies making your product reachable, which is opposite to making your product luxurious. DigitalGlobe has probably the best quality satellite imagery and is clearly determined to exploit that market advantage (see in its case study how it refused to offer its best imagery to Google Maps [119]).

The Open Business Model Pattern: Buy Innovation, Sell Innovation

Definition of **open business models** (extracted from [134]):

> Open business models can be used by companies to create and capture value by systematically collaborating with outside partners. This may happen from the "outside-in" by exploiting external ideas within the firm, or from the "inside-out" by providing external parties with ideas or assets lying idle within the firm.

The following quote is revealing:

> *Open Innovation[14] is fundamentally about operating in a world of abundant knowledge, where not all the smart people work for you, so you better go find them, connect with them, and build upon what they can do.*
>
> – Henry Chesbrough

Both DigitalGlobe and Planet Labs apply this business model pattern, although in different ways. The *outside-in pattern* can be identified in Planet Labs' business model. Planet leverages the consumer electronics industry R&D work by directly using its ready-made products –and we could say that it even uses their engineering approach as a source of inspiration. It also embraces open source software. Typically, building on externally-created knowledge allows a company to shorten time-to-market and increase its internal R&D productivity but, as a counterpart, acquiring this innovation costs money [134]. In this case, however, since Planet buys those components directly off-the-shelf, this option turns out more cost-effective than any alternative. Once again, this unveils the mystery of how Planet Labs is "breaking the schedule and cost-cycles that the space industry is infamous fo*r*" [40].

Planet is definitely also using the *inside-out pattern* when it enables others, precisely application developers, to exploit its R&D dataset. It is interesting to note that in inside-out open innovation the ideas or assets sold are typically unusable internally, for strategic or operational reasons [134]; in this case, however, Planet's R&D products sold might not be all *unusable* for the company, but rather *not fully exploited yet.* Because the high-tech industry is rapidly evolving these days, and as previously exposed, the startup is possibly using this as a temporary revenue flow and a long-term investment, for it is not permanently selling IP rights, but just granting access to its R&D dataset.

[14] "Open innovation" and "open business models" are two related terms coined by Henry Chesbrough [134].

DigitalGlobe too uses open innovation. When the company acquired GeoEye, it bought its physical and also intellectual assets (satellites and designs). This is buying innovation, or outside-in business model pattern. In fact its recent joint venture with TAQNIA in partnership with KACST, with an agreement to jointly develop a small satellites constellation that KACST will build and launch, also means exchanging innovative knowledge. The long experienced company seems to know how to take advantage of the inside-out pattern as well; this is probably what it does when it allows its DAP customers to exploit its satellites.

The Unbundled Business Models

Definition of **unbundled[15] business models** (extracted from [134]):

> The concept of the "unbundled" corporation holds that there are three fundamentally different types of businesses: Customer Relationship businesses, product innovation businesses, and infrastructure businesses. Each type has different economic, competitive, and cultural imperatives. The three types may co-exist within a single corporation, but ideally they are "unbundled" into separate entities in order to avoid conflicts or undesirable trade-offs.

These differences in economic, competitive and cultural imperatives for the three businesses are outlined in Figure 22, which helps understand the definition.

[15] John Hagel and Marc singer coined the term "unbundled Corporation" [134].

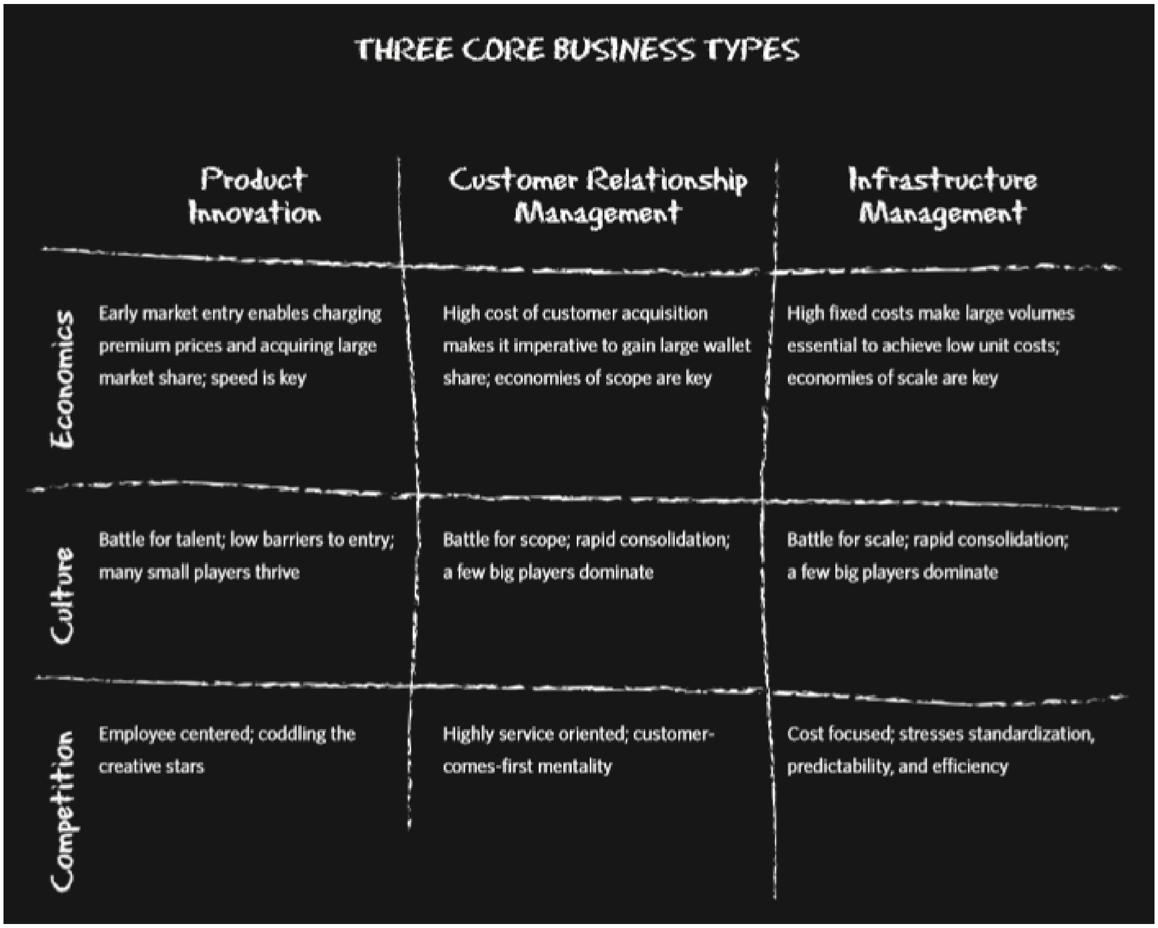

Figure 22. The three core business types and their differences in economics, culture and competition imperatives. Extracted from [6]. Original source: Hagel and Singer, 1999.

Taking into account the information in Figure 22,
Table 15 has been created to summarise how these business types dominate in DigitalGlobe and Planet corporations.

Table 15 Predominance of the three different types of businesses in DigitalGlobe and Planet corporations.

		DigitalGlobe	Planet Labs
Unbundled BM	Product innovation	✓ (early)	✓
	Customer relationship management	✓ (lately)	✗
	Infrastructure management	✗	✓

The definition of a Product Innovation business' economics (see Figure 22) makes clear that DigitalGlobe, in its earlier days, was primarily a Product Innovation business (see Table 15). Over time, its leadership position was consolidated and the corporation shifted towards a more customer-oriented approach. It could be argued that the company does have a relevant infrastructure: an IT one. But this type of infrastructure is completely unrelated to the Infrastructure Management business presented here; as Figure 22 clarifies, this business implies a physical infrastructure, with high fixed costs and mass production to compensate them.

Planet Labs does match this definition quite well; it leverages standardisation (3U-form factor CubeSats) and focuses on the scale (largest constellation ever). The startup is also akin to a Product Innovation business. However, neither of them fit in perfectly with Planet Labs' business model. The company builds large quantities of standardised satellites, but not really because it needs to compensate high fixed costs; it is simply a matter of space mission design. The key is that the unique aerospace engineering approach implemented by Planet has swept away the costly manufacturing and testing infrastructures traditionally required in the aerospace industry. And this has probably made it possible and feasible for Planet Labs to reconcile the two types of businesses.

6.4 Success Factors

Once the business models of the two companies have been comprehensively described, compared and contrasted with each other and thoroughly analysed using different business model theories, it is possible to identify their key success factors.

DigitalGlobe: Becoming a World Leader in EO

DigitalGlobe must have taken a lot of right decisions to get where it is now, but surely its first success factor was timeliness; it wisely chose the perfect moment to enter the market. Like the unbundled corporation theory states, for a Product Innovation business speed is key, and DigitalGlobe knew how to take advantage of the time without hesitation. Taking into account the state of the art at that moment (1992), DigitalGlobe also showed a bold attitude and plenty of determination and ambition. Furthermore, it was able to read the signs of the times and learn how to grow in an emerging market.

Besides, a fundamental success factor is the many and various strategic alliances and partnerships that DigitalGlobe has forged, especially in the United States but also across the world.

From the economical perspective, the combination of these two factors, timeliness and partnerships, has enabled the EnhancedView contract, which is financially sustaining the company. And with this financial cushion, DigitalGlobe has been able to invest in world-class resources (the very high-resolution satellite constellation) that in turn provide world-class products.

In terms of business model type, strengthening a leadership position as a product innovation business, together with its vast network of partners, allowed DigitalGlobe to shift its business model and focus on the customer relationship. This, added to the world-class products, results in world-class services.

Finally, the use of cloud computing is key to store, process and deliver the massive amounts of data that the company handles.

Planet Labs: Making a Difference

Cloud computing is also a success factor for Planet. Apart from that, the key to Planet Lab's success is its innovative engineering philosophy, common in the consumer electronics industry but new in the aerospace industry. The agile engineering approach along with the use of COTS components allow the company to reduce costs and streamline processes, and, in turn, helps it remain flexible and adaptable to market requirements.

Lower costs and agile development have enabled the startup to develop a unique space mission design, for building an ultra-large satellite constellation and keeping a constant constellation rebuilding process would have been unfeasible with the traditional aerospace engineering approach.

This impressive cost structure also makes it economically feasible to implement the freemium business model pattern without having secured a solid paying customer base yet.

6.5 Summary Results

The obtained results are summarised in the following table for a clearer view. It includes the Primary success factors, the Secondary Success Factors and the Consequences. The difference I make between Primary and Secondary Factors is that the companies were able to implement the latter *because* they had already implemented some of the firsts—although for DigitalGlobe all factors are indeed sequenced.

Table 16. Summary of results.

Key Success Factors	
DIGITALGLOBE	PLANET LABS
Primary factors	
Timeliness & Ambition	Agile engineering
Strategy	COTS components
Partnerships	Cloud computing
Cloud computing	–
Secondary factors	
Investment on high performance	Unique space mission design
BM shift to customer relationship	–
Consequences	
EnhancedView contract	Reduced costs
World-class products	Shortened process times
World-class services	Adaptability to market

7. Results

7.1 Conclusions

The purpose of this study was to shed light on the current presence of very different business models in the space industry by undertaking a comprehensive screening from an analytical point of view and purposely relating ideas and facts for a rich, objective outcome, while also adding my personal observations for a value-added analysis.

All of this has been done by completing the tasks included in the scope. Firstly, research has been done to write two descriptive case studies and, as it must be done for all descriptive case studies following the so-called unsequenced structure, the list of sections covered has been thought through to achieve a complete description of the cases. By means of the Business Model Canvas, the two business models have been laid out and then described in depth. The few similarities and the many differences between DigitalGlobe and Planet Labs' business models have been identified and explained. Making use of the Business Model Patterns, an additional analysis has been done to compare these two business models with existing common patterns in business models in general. And, lastly, the key success factors behind this two relevant space companies have been drawn, explained and substantiated.

This project has been subject to the omnipresent constraints of schedule and cost. If time, money and other resources (like for example power or influence) were increased, this study could be extended. For example, more companies could be added to the comparison to be able to draw general conclusions or a quantitative study could be done. Also, it would be interesting to have the chance to directly interview the spokespersons of the companies, which has been impossible as a student (they did not answer my e-mail) but could be easier with a bigger budget and a more influential role.

7.2 Safety and Environmental Concerns

This project is an analytic study which does not intend to build any object nor establish any enterprise. Therefore it has no related safety nor environmental concerns.

7.3 Economic Aspects

The total cost of this survey is estimated at 9,489.55€, mostly due to the labour cost of 375 person-hours.

For a detailed breakdown of this cost, refer to the budget (separate volume).

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